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OPERATIONS RESEARCH AND AUTOMATION SCIENCE
By Merrill M. Flood 239

NOTES ON WORK SAMPLING SAMPLE SIZE
By D. S. Holmes 242

PERSONAL JOB ANALYSIS
By C. O. Hollingshead 244

ENGINEERING METEOROLOGY
By James J. B. Worth 249

COMPUTING MACHINES: RENT OR BUY?
By William Haynes Starbuck 254

GERMANY AND INDUSTRIAL ENGINEERING
By E. C. Keachie 259

PRODUCTIVITY AND INCREASED WAGES
By Robert B. Seidel 263

WORK SAMPLING BY FIXED INTERVAL STUDY
By I. Landis Haines 266

PRESIDENT'S MESSAGE
By Gordon B. Carson 269

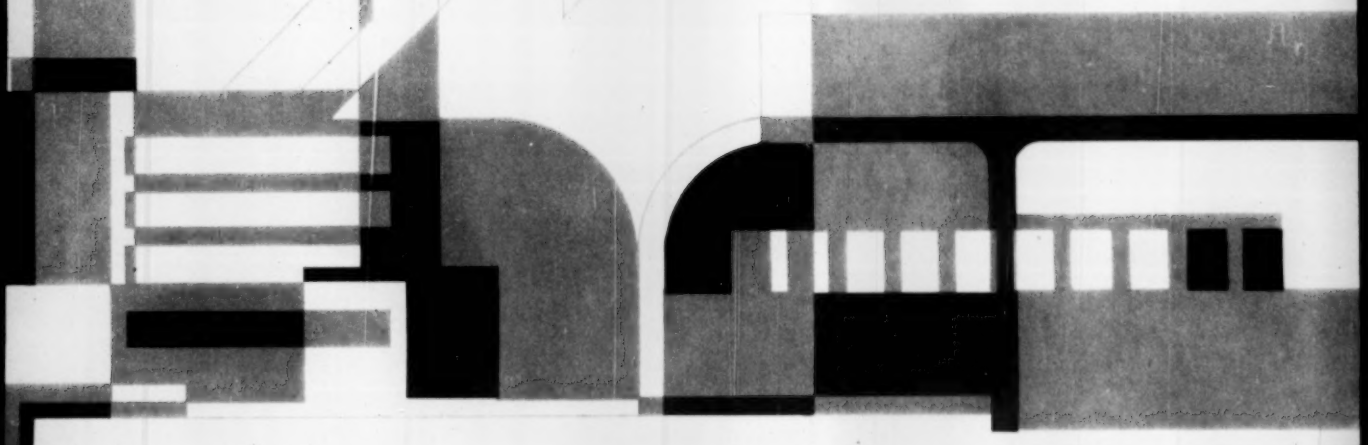
PRESIDENT'S MESSAGE
By George H. Gustat 271

READER COMMENTS 275

INSTITUTE INTERESTS 277

RESEARCH ABSTRACTS 284

I. E. OPPORTUNITIES 302



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Operations Research and Automation Science[1]

by **MERRILL M. FLOOD**

Professor of Industrial Engineering, The University of Michigan

AUTOMATION, to some, is a promise of better living. To others, it threatens unemployment. To all, it is a fact of increasing importance and a modern sign of a rapidly advancing technology.

The Hiroshima bomb brought science and scientists into every home. Scientists totally unaccustomed to participation in public affairs found themselves suddenly in the public eye—giving advice to legislators and industrialists on the implications of atomic energy, and of science generally, for everyday life in the future.

High-speed electronic computers compete with atomic weapons for top billing among the stars of science today. Machines that "think" and "learn" are now popular topics for the literature of science, as well as for that of science-fiction. There are published accounts of machines that translate from one language to another, that play chess and poker, that compose melodies, that state and prove mathematical theorems, and that do a startling variety of other tasks commonly felt to be too difficult for any but humans.

Scientists have teamed together to find better solutions to old problems met in managing private enterprises and governmental organizations. As "operational research," a team of British scientists has been credited with a major part in winning the Battle of Britain in World War II. As "operations research," and "operations analysis," teams of American scientists have been credited with major contributions to the success of many military activities during and since World War II. As "operational research" in Great Britain, and as "operations research," in the United States, teams of scientists have also made substantial contributions in many non-military areas since World War II.

This paper is concerned with the relationship between operations research and automation science, and especially with the ways in which scientific work on management and operations contributes to the advance of automation.

THE NATURE OF AUTOMATION

Many of our most important technological advances may be considered as mechanical substitutes and extensions for human sensing, motor, communication, and control functions. A few examples in each category are:

1. *Sensing.* Binoculars, seismographs, infrared scanners, sonar, and radar.
2. *Motor.* Fork lifts, drag lines, bulldozers, transfer machines, and airplanes.
3. *Communication.* Public address systems, telephone, radio, and television.
4. *Control.* Servomechanisms, autopilots, adaptive filters, and automatic inspection devices.

Mechanization does not necessarily constitute automation, unless the function mechanized was previously considered to be one that was fundamentally human in character.

For example, the automatic transmission for the automobile substitutes for a traditionally human operation, that of shifting gears manually when the situation is judged to make such a change desirable. A technological change of this kind is often considered to be an example of automation simply because it constitutes mechanization of a function previously performed by the human.

The dial telephone substitutes for some functions previously performed by humans, and ones that required high-level perceptual and manipulative skills, so the technological advance it represents is apt to be called automation—at least until it becomes so commonly accepted as a mechanical device that the earlier human aspect is essentially forgotten. The push-button self-starter in an automobile would certainly not now be thought of as automation, just as the automatic transfer machinery of the automobile industry is not apt to be considered automation in a decade or so.

The essential nature of automation is the mechanization of functions that were not only previously human, but believed to be fundamentally so because of disparity

[1] This paper was prepared while the author was Professor of Industrial Engineering and Director of the Institute for Research in the Management of Industrial Production at Columbia University, and was presented at Rock Island Arsenal, on 24 May 1956, at the Third Annual Ordnance Conference on Operations Research sponsored by the Office of Ordnance Research and the Ordnance Weapons Command. The work was supported in part by the Office of Ordnance Research, under Contract No. DA-30-069-ORD-1622 with Columbia University. Reproduction in whole or part is permitted for any purpose of the United States Government.

between technological capabilities and apparent requirements of the task.

This says little more than that automation is clever and surprising mechanization. Automation is simply a dynamic word for change.

AUTOMATION SCIENCE

Progress in automation has been largely a technological advance through invention. It has been aided very little by general scientific theory, such as that given to mechanical engineering by Newton's laws of mechanics and the engineering principles that follow from them. This is perhaps not too suprising, since automation science should include some good science relating to human capabilities and behavior, and progress in behavioral science has been disappointingly slow.

The automatic pistol is a useful example. Until an inventor had the idea of using the energy from the explosion to actuate the reloading mechanism, and an economical and reliable design was found for this, there was no mechanization of the reloading function. A design problem of this type is still solved today in pretty much the same way, by engineering art and experience, with military automatic guns of large caliber. However, the ordinary pistol is still aimed by the human whereas many of the larger guns are now aimed automatically—a development that seems to depend rather fundamentally on fully mechanized radar range and direction finding.[2] Conceivably, as electronic miniaturization advances, a handheld pistol of the future may be fired automatically and accurately in complete visual darkness with the human operator having only to decide whether the target is friend or foe.

More interesting opportunities for automation science are met in designing automatic switching gear for telecommunication systems, or automatic air traffic control systems, or automatic refinery control systems. Important use has been made of servo-mechanism theory in control system design only for about a generation. Even in the telecommunication field, it is only for a part of this generation that use has been made of scientific disciplines such as information theory and symbolic logic. Only very recently are scientific disciplines such as mathematical programming theory, and statistical decision theory, being used in the design of automatic refineries. These five disciplines, and variants of them such as the logical theory of automata or time-series theory, constitute about all that there is in the way of automation theory today.

It is significant that all of the disciplines listed here as relevant for automation science are also very popular as tools for use in operations research. Our main thesis is that operations research provides exactly the kind of precise mathematical descriptions of systems that are needed by the automation engineers who wish to mechanize so as to optimize system performance, and especially so with regard to those decision-making functions performed formerly by human managers and operators.

FIELDS OF AUTOMATION

The term automation has become popular because of the tremendous social implications of rapid mechanization of manufacturing processes—a field of automation that is here identified as "manufacturing automation," with the completely automatic factory or the completely automatic refinery as the ultimate form.

As the term is now used, the automatic plant must be constructed, maintained, monitored and managed by human beings. The industrial organization might include several automatic plants manufacturing several different products. The management of the organization must still make many decisions concerning production rates, product distribution, pricing policies, growth plans and the like. Even some of these traditionally human managerial functions are being mechanized in part—a field of automation here identified as "management automation."

The staff elements that gather and process information for management use, such as accounting and engineering units, employ procedures that can sometimes be mechanized in part—a field of automation that is here identified as "office automation," with the completely automatic office as the ultimate form. Although office automation seems to be simply a continuation of a well established trend toward mechanization of office routines, developments such as ERMA by the Stanford Research Institute for the Bank of America are sufficiently clever to constitute automation.

The broad field of manufacturing automation includes four identifiable subfields, that are worth naming here for purposes of further discussion:

1. *Automatic machining.* In the metal-working field, a few in the sequence of automated machine tools are: screw-cutting lathe (1800), profile copying lathe (1818), turret lathe (1854), automatic lathe (1870), transfer-machine (1924), and tape-controlled tools (1950). Examples of automatic production machinery are modern packaging machines, mixing machines, foundries, reactors, and a host of other machines that change the physical form and composition of materials and components.

2. *Automatic assembling.* Recent advances in the methods of manufacturing electronic equipment, such as computers and television sets, have depended heavily upon automatic assembly of components into finished subassemblies and assemblies.[3] Advances

[2] Dr. T. C. Fry, formerly with the Bell Telephone Laboratories, has pointed out that trans-Atlantic telecommunication would be fundamentally impossible without feedback amplifiers operating automatically at repeater stations. Here is another example, the automatic feedback amplifier, of a technological advance that seems essential for automation regardless of willingness otherwise to devote men and resources to the purpose.

[3] The author outlined a way in which linear programming theory, applicable to the traveling salesman problem, could be used in designing an optimum automated assembly line for producing electronic chassis and similar items in his talk given at the First Annual Ordnance Conference on Operations Research at Frankford Arsenal in 1954.

in automatic assembly have also been important in the automotive industry, as a step beyond automatic materials handling accomplished by transfer machinery. Many packaging and bottling lines constitute examples of highly mechanized materials handling and assembly processes. These are all examples of automatic assembly machinery, that move and combine parts and components without appreciably altering their form or composition.

3. *Automatic controlling.* There are many familiar examples in which a production process is observed during operation, and the information so obtained is used as the basis for decisions determining controls imposed upon the process to alter its subsequent characteristics. In many cases, as in the chemical industry, observation and control is sometimes done by human operators and sometimes by automatic equipment. This subfield of automation, which has been called "cybernetics" by Wiener, is distinguished by the feedback feature. It has received a great deal of attention in recent years, and similarities have been noted between properties of mechanical systems with feedback and those of learning and decision-making in humans.

4. *Automatic programming.* Machining, assembly, and process control are manufacturing operations that are rather completely determined by product design and manufacturing specifications. Planning, programming, and scheduling the work of a plant so as to meet changing production requirements promptly and efficiently is the responsibility of the plant superintendent. In a typical chemical plant, for example, a staff of production engineers must make frequent analyses in an effort to determine plant operating conditions that will best yield required product output. Modern electronic computers, and mathematical programming techniques, are now being combined to provide automatic production scheduling. The superintending function is that of choosing among the many possible ways of operating a plant, whose technical characteristics are fixed, so as to achieve maximum efficiency. Production scheduling is one part of this function. Automatic programming constitutes another important subfield of manufacturing automation. Thus, automatic control enables the system to adjust itself to meet changing conditions observed internally, whereas automatic programming enables the system to adjust itself efficiently to changing requirements imposed externally.

AUTOMATION ECONOMICS

Operations research and systems analysis techniques are now in rather widespread use for evaluation of alternative weapons systems. A typical problem of this kind would be to determine whether or not to replace strategic bombers by long-range guided missiles in order to achieve some military goal described in terms of desired destruction capabilities. A military problem of this kind is conceptually like ordinary replacement questions in industry—should some machine tool be replaced, should some plant be automated, or should some building be replaced?

The weapons systems analyst, or the engineering economist, would normally analyze the old system in comparison with the proposed new ones to determine which is best suited for current purposes. Attention would be given to the plans and systems of enemies, or competitors, and careful quantitative estimates of the probable outcomes under each alternative would provide a basis for sounder comparison and decision. Analyses of this kind very often require the use of a mathematical model capable of representing the various alternatives under consideration in precise and manipulatible form. The model will sometimes be a relatively simple one, like the familiar economic replacement formulas that provide for service life and investment schedule effects, or it may be a very complicated one representing a many-parameter family of technological possibilities and their corresponding economic worths.

At the operating level, a mathematical model might be useful in determining the most economical among several possible inventory control policies. Or a mathematical formula might be used to represent the cost of machining a production run of items in terms of operating parameters such as cutting speed and feed, in order that optimum operating conditions could be determined mathematically as the ones minimizing total cost.

The economic analysis of design and operating problems of this kind is typified by the following example, relating to the automation of a large refinery by a petroleum company. The essential data for the analysis are broadly as follows:

$u(t)$ = Crude input during time interval t (varies with vendor),
$v(t)$ = Process settings (those usually at disposal of plant superintendent),
$y(t)$ = Product output (a stochastic function of u and v at prior times),
$D(t)$ = Product value (dependent upon actual demand and price structure, including penalties for overage and underage).

A completely automatic refinery would be fed forecasts of expected crude input and demand-price quantities, and would continuously choose process settings so as to maximize some given function of product value over the future. It is interesting to note that an automatic refinery of this kind would also automatically shut down under certain conditions, and equally automatically begin operations again when conditions were more favorable for profitable operation! The initial decision to acquire an automatic refinery, instead of some more conventional form, requires that the estimate of its future profitability certainly exceeds returns anticipated from more common methods of operation. There is a persistent rumor that at least one large chemical company has nearly finished the construction of just such an automatic refinery.

A much simpler example, and one of interest to the present author as a prototype for such analyses, relates to the desirability of using a machinability computer to substitute for the judgment of skilled machinists in setting cutting tools at optimum speed and feed. The essential data for this analysis are again broadly as follows:

$u(t)$ = Material and job characteristics (as per stock and blueprints),
$v(t)$ = Process settings (those normally at disposal of machinist),
$g(t)$ = Product output (a stochastic function of u and v),
$D(t)$ = Product value (including penalties for rejects and poor quality).

A machinability computer, or its equivalent in speed and feed tables, is simply a quick means for replacing certain individual judgments by a mathematical formula that represents a vast accumulation of experimental and theoretical knowledge relevant for this particular decision-making situation. Even in this relatively simple case, it is very difficult to determine whether or not the computer is more skilled than the machinist and, if so, also more economical. Certainly, answers to questions of this kind are needed before mechanization of equivalent and familiar human functions can be considered certainly economical and desirable.

The cases of the automatic refinery and the machinability computer show the intimate ties between the key aspects of operations research and the practical problems of automation engineering. Typically, the efficient design and operation of a complex automatic system requires full use of very nearly every technique and tool available from operations research and automation science, including the modern high-speed electronic computer both as a tool for analysis and as a component of the automatic system itself.

Systems engineering and engineering economics are two other familiar names for design and evaluation work like that under discussion here. Physical and economic characteristics of complex systems must both be understood well before wise choices can be made among alternatives available to perform comparable functions. Operations research methods and theories help to provide the techniques and rationales needed for analyzing such alternatives in the search for optimum solutions.

CONCLUSION

The automation of a system can normally be done efficiently only after a precise specification of the system's function is available, and a systematic evaluation of alternative designs and of alternative operating procedures has been completed so that an optimum solution may be selected. Operations research is of critical importance in choosing optimum system designs and system operating procedures.

Since, by its very definition, automation means the efficient substitution of machines for humans, automation science includes knowledge both from the physical and the human sciences. There is an increasing need for human behavioral science, and for management science, as successful automation of complex systems depends more and more upon human and economic factors. These areas of science are tending to fuse into one as control and decision technology is applied in similar manner to man and machine components of complex systems.

High-speed electronic computers, and realistic system models, are key components both for developing automation science and for design and construction of particular automated systems. Automatic refineries, and automatic offices, seem to represent the most advanced forms of automated systems combining substantial physical elements and logical decisioning components.

It is a safe conclusion that the vigorous work on operations research and automation science now in progress will hasten the advance of automation, and will also make it better meet the human and economic needs of us all.

Notes on Work Sampling Sample Size

by **D. S. HOLMES**

Operations Research & Synthesis, General Electric Company, Schenectady, New York

ONE of the problems of work sampling is the size of the sample required to give a predetermined degree of accuracy. Most of the literature on this subject offers variations on the theme of the sample size required to do a given study. As a result of the large sample size and the cost involved, many such studies go undone.

Another approach to the problem is to take a small sample which will cheaply tell whether or not a full-blown study might be in order. One attack of this type is given in the following paragraphs. Using this method, a full study will not be taken unless the small study gives evidence that at least one man can be transferred to more productive duty. With this in mind, the hypothesis that the non-working time of N men is greater than $\frac{1}{N}$ is tested. If the non-working time exceeds this figure (or this figure plus an allowance for non-productive time) then a full study may be warranted since one or more men may then be transferred to other duty.

The null hypothesis set up is $H_o : nwt < \frac{1}{N}$ (nwt = non-working time). If this hypothesis is rejected, then a full study is conducted. If this hypothesis is accepted, then we do not bother to conduct the study. (Note: This assumes that the study is being taken as a basis for action rather than information research.)

This null hypothesis is tested using a criteria P_d which is based on the sample size and a degree of assurance. If the fraction of non-working time of the sample exceeds

FIG. 1

P_d the null hypothesis would be rejected and a full study conducted. If the fraction of non-working time of the sample is less than P_d, the null hypothesis would be accepted and a full study not conducted.

It is possible to get values of sample *nwt* greater than P_d even if the true value of *nwt* is $\frac{1}{N}$ or less. If this occurs, then a decision "make a full study" will be reached when the decision should have been "don't make a full study." Suppose it is decided in advance that a wrong decision of this type should occur no more than $100\alpha\%$ of the time.

On the other hand, it is possible that the sample value of *nwt* will be less than P_d even if the actual *nwt* is greater than $\frac{1}{N}$. If this occurs then a decision "don't make a full study" will be made when the decision should have been "make a full study." The protection set up here can vary, but one possibility is to say that if the actual *nwt* is $\frac{2}{N}$ or greater, a wrong decision of this type should occur no more than $100\beta\%$ of the time.

Next, it is assumed that the sample *nwt* fractions are normally distributed. Given these assumptions, it is possible to derive the following equations for:

1. The sample size required to make the decision whether or not to take the full study.
2. The sample criteria P_d.

These equations are given below:

Sample Size—n

$$n = \{Z_\alpha\sqrt{N-1} + Z_\beta\sqrt{2(N-2)}\}^2 \quad \text{Eq. 1.}$$

Where Z_α is the one tailed Normal Distribution value corresponding to a probability α and Z_β is the same corresponding to a probability of β.

N = Number of men in group being studied ($N \geq 3$). If the degree of assurance is the same for each type of error ($Z_\alpha = Z_\beta = Z$) then the value of n can be quite well approximated from the equation: $n = (5.83\ N - 9.30)^2 Z^2$.

A nomographic solution for this equation is shown in Figure 1.

Sample Criteria—P_d

$$P_d = \frac{(Z_\beta\sqrt{2(N-2)} + 2Z_\alpha\sqrt{N-1})}{N(Z_\beta\sqrt{2(N-2)} + Z_\alpha\sqrt{N-1})} \quad \text{Eq. 2.}$$

If the degree of assurance is the same for each type error ($Z_\alpha = Z_\beta = Z$) then the value of P_d depends only on N. The table below gives values of P_d for N up to 25 under these conditions:

N	P_d
3	0.500
4	0.366
5	0.290
6	0.240
7	0.205
8	0.179
9	0.159
10	0.143
11	0.130
12	0.119
13	0.110
14	0.102
15	0.095
16	0.089
17	0.084
18	0.079
19	0.075
20	0.071
21	0.068
22	0.065
23	0.062
24	0.059
25	0.057

EXAMPLE

Suppose it is desired to make a preliminary study on a group of 10 people and to have an assurance of 5% against each type of error. The nomograph reads a solution of about 130 observations. The table for P_d reads 0.143. Thus, a sample of size 130 should be taken. If the fraction of non-working time should exceed 0.143, then a full sized study should be undertaken.

SUMMARY

A method is suggested for taking a small sized work sampling study to see whether or not a full sized study should be undertaken. The formulas developed are displayed in graphical and tabular form for the case where the assurance against each type error is the same.

Personal Job Analysis

by C. O. HOLLINGSHEAD

Supervisor of Industrial Engineering, Sylvania Electric Products, Inc., Shawnee, Oklahoma

MANY employees in technical, clerical and managerial positions have trouble finding time to perform all the tasks which seem essential to their jobs. The inability to perform all necessary work within a given time period leads to frustration. Such frustration is frequently compounded by a somewhat instinctive realization that beneficial changes could be made if only more knowledge existed concerning the impediments to accomplishment. The techniques described in this article are believed to offer an approach to this problem and also may be of benefit in alleviating a pressing shortage of technical and clerical personnel by suggesting changes in job design and work load distribution.

A COMMON PROBLEM

Recent competition among the major U. S. Corporations in securing their needs for engineers have served to popularize this crucial shortage. However, competent stenographers, secretaries, trained technicians and managerial personnel are also in tight supply, and in all cases the outlook is for existing shortages to become worse.

It has been stated frequently that the greatest single action which could and should be performed to ease the shortage of engineers is to make better use of the engineering staffs already employed. Such suggestions usually speak of greater use of technicians and clerical help to free up more engineers time. It has recently been observed by a prominent educator that a mere 5% increase in efficiency in our present 600,000 engineer work force would add to the supply by an amount equal to our current number of engineering graduates. The techniques which will be described in this article were employed in a survey of our engineering department, but the principles may be used by anyone who has a job to perform either in or out of industry. Fortunately, these procedures may be altered to provide the information which suits an individual need or desire.

ONE EXPERIENCE

The application of these techniques in one Industrial Engineering Department yielded the following summary of time distribution for seven Industrial Engineers for a twenty-five day period. All time spent during the study period was classified into each of the three mutually inclusive distributions as tabulated on the following page.

The study participants classified all of their time into one item under each of the three classifications shown. Special rules were followed by all departmental members who participated in the survey in order to improve the reliability and meaning of the results.

One illustration of an action which resulted from this study may be seen by referring to Classification II. The study participants classified the time spent on work which it would have been possible to delegate to a technician or clerk into the B or C part of Classification II if the work was of such a nature and duration that it would have been practical to do so.

Since seven Industrial Engineers took part in the survey and the percentage of time which could be delegated to a technician or clerk totals 19.6%, it appeared that the equivalent of one additional Industrial Engineer would be added to the department by the creation and subsequent filling of a position which combined these functions. This action has been taken and additional studies are planned as soon as the job incumbent of the newly created position is fully trained.

A primary objective of the study summarized above was to check the distribution of departmental members time. This knowledge then served as a guide to distributing departmental assignments, equalizing work loads, and, as already mentioned, determination of the nature and extent of a new position in response to a need for additional output. As will be seen, the techniques employed to make the study may be altered in numerous ways to provide answers to specific questions about other departmental activities. The greatest limitations are the time consumption in properly instructing the study participants, making the study, and summarizing the results.

Similar approaches using work sampling techniques which are applicable to supervisory functions are outlined by some authors (1) (5). Determination of their applicability will involve consideration of the questions which should be answered concerning time distribution, job variability, and difficulty in conducting a study. Other writings in the field of work sampling touch upon the statistical considerations and practical difficulties of investigating such work (2) (4) (5).

INDIVIDUAL SURVEYS

Any improvement in a job responsibility is more readily installed for lasting benefit if based upon definite quantitative knowledge of the present content of the job.

ENGINEERING TIME ANALYSIS SUMMARY

Classification I		Classification II		Classification III	
1. Work Measurement		A. Engineering	80.4%	A. Planning	8.2%
Direct Labor	27.1%	B. Technical	14.0	B. Performing	44.4
Indirect Labor	7.9	C. Clerical	5.6	C. Calculating	20.1
Expense Labor	7.2		100.0%	D. Communicating	
2. Methods	5.4			Verbal	12.3
3. Wage Administration	6.1			Written	5.9
4. Plant Layout	3.1			E. Non-Productive	9.1
5. Cost Reduction	5.5				100.0%
6. Training Classes	6.1				
7. Personal	10.2				
8. Miscellaneous	10.3				
9. Reading Circulated Material	4.6				
10. Time Analysis	6.5				
	100.0%				

As will be outlined in this article, it is proposed that this knowledge be obtained by means of a survey of job content.

It is suggested that the initial step be a preliminary analysis of ones own job. If this personalized survey is successful, the reader is left to his own devices in making use of the survey technique on a departmental basis.

To begin a survey of your own job, careful thought should be devoted to defining its major elements. To determine the answer to this question try keeping track of your time throughout the course of several working days. A wrist watch is almost a necessity to this procedure. In attempting to divide your individual time a problem occurs almost at once involving the precision with which you want to conduct the survey. For example you may be midway to completion of a letter concerning a sales problem on Product A when the boss calls and ties you up for approximately three minutes with a question concerned with material for Product B. You naturally wonder if a notation should be made to this effect and listed in the analysis. The answer to this question must be determined individually. Since it will be recommended that a period of at least 4 weeks be chosen as the length of time to be surveyed you are probably safe in ignoring time intervals of less than two minutes duration. If you suspect that certain parts of your day are subject to frequent interruptions and you wish to check on the frequency of such interruptions, a simple way in which this can be done will be explained later.

You will soon discover that individual time analysis is no exception to the expressed rule that all worthwhile things have a price. In this case the price is time and inconvenience. For example, if you attempt to keep track of every occurrence which exceeds two minutes and the number of factors which you are using in your survey approximately 20-30, you will probably have to spend six hours summarizing the results. Any busy person is reluctant to invest time of these proportions and will do so only if convinced that the information which will be obtained should make it possible to break-even from a time investment standpoint in a very short period. A properly designed survey sheet and code will also make it possible to delegate the clerical task of summarizing the results. If you plan on summarizing the results yourself a good code and sheet design can hold your time investment to a minimum.

EARLY EXPERIENCE

The normal reaction when an individual surveys his time is one of surprise at the effect which the survey has on his own performance. Time which before was spent in light discussions of the weather, last night's bridge game, or Saturday's golf highlights is brought to the forefront and, if the survey is kept impartially, dutifully classified under a heading marked personal or non-productive. Usually, unless an effort is made to counteract the tendency, the survey itself brings about improvements of some time wasting practice which therefore never gets a chance to be shown or adequately measured.

After several days working time have been surveyed, one is ready to choose the elements or categories which cover the major portions of his job. This is a critical point in the analysis, since decisions then made may lead to abandonment of the project in disgust, instead of experiencing the satisfaction which a well conceived and executed analysis can bring.

Among the decisions which must be made is not only the number of major categories into which the work should be divided but also whether a separate breakdown or classification of any time element will be used. It is theoretically possible to use a considerable number or subclassifications of a single time element. This practice of intensive subclassification, although tempting to the beginning analyst, does increase the complexity of the final analysis and summarization and frequently does not provide information of tangible value. A good question to ask yourself before adding a subclassification is, "Of what significance will it be if the summarized data shows this item to be a higher or lower proportion of my total time than I now believe it is?"

A TYPICAL EXAMPLE

The techniques employed can perhaps best be described by choosing a theoretical example of an engineering supervisor of a department having responsibility for the design work on a product composed of several complex subassemblies. As suggested previously, he may wish to precede a survey analysis of all in his department with an investigation of his own time. A preliminary survey leads him to conclude that his job may best be divided into classifications as follows:

1. Administration
2. Meetings
3. Design—Component A
4. Design—Component B
5. Testing—Component A
6. Testing—Component B
7. Drafting
8. Material Procurement
9. Sales
10. Miscellaneous

The ten classifications chosen may overlap easily if some method is not adopted to provide the result desired. For example the supervisor may find himself attending a sales meeting. The problem will then occur concerning whether to classify the time spent in the meeting under the classification of sales or under meetings. This problem may be resolved by adopting a separate classification system.

It is desirable to account for all time spent in order to facilitate the analysis and summarization. To do this the analyst can change the previous number of headings to a total of nine by separating the Meetings classification and including it in a separate group of additional classifications. Since the first group was numbered the second group of classifications can be lettered A, B, C, etc.

Since it is always handy to know what proportion of time is spent in talking or verbal communication it will probably be desirable to include a category marked B which covers all time spent in this manner. All time then, on any subject which was used mainly in discussion, would be coded B. A category coded C could then be used for all time spent in writing letters, memos, or other forms of written communication. Perhaps a third category into which all time not spent in meetings, verbal communications or written communications, coded D, could be used to classify all time not spent in performance of a previously classified function. For reasons to be explained later, it is desirable to include at least one category entitled Personal and one entitled Miscellaneous in the original list of classifications.

At this stage we have two sets of categories as follows:

Set I	Set II
1. Administrative	A. Meetings
2. Design—Component A	B. Verbal Communication
3. Design—Component B	C. Written Communication
4. Testing—Component A	D. Performance
5. Testing—Component B	E. Personal and Miscellaneous non-productive
6. Drafting	
7. Material Processed	
8. Sales	
9. Personal	
10. Miscellaneous	

Item E under Set II, entitled Personal and Miscellaneous non-productive, is established as more or less a catch-all classification for all time not properly classified in the remaining subject headings of Set II. It should be emphasized at this point that the classification under Set II can be altered in any manner to suit the purposes of the analysis. For instance if the analyst wishes to know how much time he spends in verbal communication over the telephone he has merely to create a category for this purpose and code all time spent talking over the phone into the letter designated. If he wishes to know who he spends his time talking to, a separate code may be utilized which will provide the answer. At this point it is well to remember that each addition to the codes adds another complication to the analysis which increases the time which must be spent in summarization.

Possibly our supervisor wishes to know whether he could use the services of a full time assistant. The answer may be made clearer by the addition of still another set of classifications to his main group. This set, which will be called Set III, may be headed as follows:

Set III

a. Work which could be delegated to a trained assistant
b. Work I will always perform myself
c. Miscellaneous non-productive, personal, etc.

Again the c classification is provided as a catch all for time which cannot properly be placed in either a or b in order to make the time totals of a and b more meaningful when the final results are in. The analyst in this case will need to make allowance in evaluating the results for the fact that all time classified under Set III will have to be adjusted to allow for time he will need to spend giving instructions to the assistant involving the work delegated.

A GENERAL EXAMPLE

If the supervisor in question has plans for installing a similar analysis among the engineers and other personnel in his section he may wish to modify Set III as follows:

Set III (Alternate)

a. Engineering
b. Technician
c. Engineering Aide
d. Clerical
e. Miscellaneous non-productive, personal, etc.

If the engineers in performing their individual surveys will code their time in such a manner that all work now done by them which could be performed by a technician, engineering aide, or clerk is placed in the proper category, the needs of the department for additional help and the job classification requiring additional help may be pinpointed.

Some thought and time will need to be spent in developing and explaining the rules governing the use of a given time classification in order to achieve uniformity between persons when more than one person participates in an analysis following the same outline. It is recom-

mended that all rules which each member of the group is asked to follow be summarized in writing and a personal copy provided at the start of the survey period.

The actual analysis is a matter of habit. At first it is somewhat annoying to have to stop at the completion of one item and take the time to record it properly. As stated previously the summarization itself can be a time consuming procedure. In order to make it possible to delegate the clerical work in summarization and to make it easier to record the distribution of time expended, a coding system of recording is highly recommended. A sufficiently large sized piece of paper (5″ × 8″ is usually preferred) should be chosen and ruled on the left hand side into two columns. The first column should be large enough to record the time of day. The second column should be large enough to record 3 digits and the remainder of the page may be left blank to accommodate the code and other items of information which are considered worth checking. It is recommended that the paper chosen be lined horizontally with spaces about ¼″ apart.

In the case of the engineering supervisor with the set of three classifications a portion of a code sheet for one day may appear as follows:

Time	Elapsed Time	Code
8:00		Start
8:35	35	2Ba
8:45	10	8Cb
9:30	45	8Ab

Using the system shown the analyst only needs to record the code and the time of day, although the space following the code may be used to note the frequency of interruptions. All further summarization can be performed by a clerk with a minimum of instruction. In the example shown the supervisor has come to work at 8 o'clock and become involved in a design problem on component A. He has spent the time between 8:00 A.M. and 8:35 A.M. discussing the problem. Accordingly he codes the time 2Ba to show first that it involved design on component A and second that, for the most part, he discussed the problem with someone else. The last part of the code, a, illustrates that he considered the item to be of such a nature that it could be handled by an assistant. The next code item 8Cb illustrates the dictation of a letter involving a sales problem. He obviously considers this part of his time to be of such a nature that he should do it himself and normally it can't or won't be delegated to an assistant. The next coded item 8Ab illustrates his attendance at a Sales meeting and that this too is an item of time not normally to be delegated.

SUGGESTED PERIOD FOR STUDY

It is recommended that a period of at least four weeks or one month be chosen as the time period to be covered by the analysis. Such a length of time normally will cover the cyclic fluctuations in a working month. Of course, if it is known that the job to be studied is subject to cyclic variations greater than one month in duration then, if these variations are thought to be significant, it will be necessary to conduct the study over a more extensive period of time. Likewise a shorter period of time may provide significant results on more routine jobs.

The first week's data should be summarized as quickly as possible. It will be noted that if a data form similar to that described is used it will be easier to summarize the data between the 3 sets of classifications shown by simply blocking out all columns but the one being summarized. Summarization at the end of the first week is highly recommended in order to make certain that the miscellaneous category is not being used excessively. It is a good practice to briefly describe in writing all items which are coded miscellaneous in the space following the code. Then, if miscellaneous totals in excess of 10% or some predetermined figure, the items so classified can be analyzed and a coding may be applied to determine their extent and class. In this manner a degree of protection is afforded if the original coding system is not complete and the code design may be altered at any point in the analysis without the loss of data collected up to the point of design change. Upon completing the individual analysis and summarization of results the final steps, interpretation of results and follow up action for improvement, remain.

A continuation of the analysis for sufficient time to produce significant results and a summarization of the data may show the following:

Set I	
1. Administrative	10.0%
2. Design—component A	8.0
3. Design—component B	13.0
4. Testing—component A	6.0
5. Testing—component B	18.0
6. Drafting	2.0
7. Material Procurement	4.0
8. Sales	20.0
9. Personal	7.0
10. Miscellaneous	12.0
	100.0%

Set II	
A. Meetings	15.0
B. Verbal Communication	40.0
C. Written Communication	5.0
D. Performance (reading reports, studying operations, etc.)	30.0
E. Personal & Misc. Non-Prod.	10.0
	100.0%

Set III	
a. Work which could be delegated	35.0
b. Work always performed myself	55.0
c. Miscellaneous non-prod., personal, etc.	10.0
	100.0%

SUMMARY OF ANALYSIS

The sample summary shown is, of course, theoretical and is meant to show some of the results which may

occur. A study of Set I reveals that the largest items are Sales, testing component B, design component B and miscellaneous. In Set II the percent of verbal communication and meetings are of particular interest. In Set III the percent of work which could be delegated was the time which our analyst particularly sought to check.

It would seem in this example that the item, testing—componet B, in Set I is high in proportion to the Design and Testing Classifications. Our analyst may conclude upon noting the extent of this item that the reason lies in the existence of inexperienced personnel who still require a high proportion of training time. Then too, it may reveal the existence of a problem that he was vaguely aware of previously but which now has a quantitative value.

Sales in this case is a large item and analysis of the Sales and Meetings account may reveal that a majority of both are inter-related. If this account was not already classified as being one which could be delegated to an assistant, the data would then point up the value to be achieved by such an arrangement and may bring about a shift in the departmental manager's thinking regarding the qualifications he will need to seek for the man who will fill this job.

The miscellaneous classification in Set I at 12% may be further investigated for the existence of a procedure which should really be classified separately. Item E of Set II and item e of Set III are catch-all classifications which mainly exist so that the remaining items in these sets may have truer significance since all items which do not belong in one of the other categories should be placed in these.

The manager will need to consider the alternatives suggested by his classification concerning the possible use of an assistant. Of course the assistant must have something else to do in addition to the duties earmarked for him by the time analysis. It may be that the creation of two or more section head or group leader type positions to share the duties which he wishes to free himself from, may be the most practical answer.

The problem in testing component B will need to be investigated and perhaps some changes planned which relegate this assignment to its proper proportion of department responsibility.

The manager will perhaps seek and find ways to improve his ability in verbal communication when he sees how great a proportion of his time is spent in this activity. He may become more critical of time spent in meetings and seek ways to use part of the time now in attendance at a meeting for some other use, such as the reading of correspondence, the writing of memoranda and partially planning future department operations.

APPLICATION OF ANALYSIS

Forearmed with the knowledge gained by a good job of recording and summarization the analyst is ready to start the detailed planning and observing which will lead to eventual improvement. To date other than having made the possibly shocking discovery that so much of his time is devoted to satisfying his personal needs, despite reductions made during the analysis itself, he has mainly experienced the additional trouble of filling out the daily code sheets and in completing the analysis. He now is in possession of information which will assist him in making improvements, but follow-up is necessary if any lasting improvement is to be realized.

It seems wise to continue an analysis once started in order to have the value of comparison with a past record and to assure oneself that the improvements installed have actually been realized. A desirable frequency for such a restudy will probably not be less than 6 months depending on departmental or job conditions at the time a restudy is contemplated. At this time there is reason to believe that sufficient repetition of the procedure which has been outlined serves to develop a continued awareness of ones time utilization practices. This consciousness of habit patterns, if accompanied by creative analysis of the data produced from previous surveys, will tend to diminish the returns of future surveys to the extent that improvement has resulted. The reader is left to his own devices in evaluating potential results of future surveys, but it does seem that no real analysis can be made until a history of surveys is accumulated. This procedure, in common with others encountered by the writer, pays dividends in proportion to the effort, creativity, and persistent follow-up employed in its execution. This article has emphasized mainly a technique which is expected to reduce the burden of collecting essential information which in turn can be best handled and interpreted by the person making the analysis.

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Engineering Meteorology

Air Conditioning As A Factor in Attaining High Rates of Industrial Production—Personnel Efficiency[1]

by JAMES J. B. WORTH[2]

Meteorological Laboratory, University of Michigan

THE effects of high temperature and humidity on work efficiency were first investigated in the late nineteen twenties. Results very strongly indicated that temperature and humidity above a critical point would reduce both mental and physical efficiency. A few companies have tried plant-wide air conditioning and the results indicate a 10 to 25 percent increase in productivity.

INTRODUCTION

The influence of atmospheric conditions in factories and shops upon the health and well-being of the occupants cannot be overlooked. Research engineers such as C. P. Yaglou and W. J. McConnell began studying controlled experiments as early as 1922 (7). The industrial worker spends the major part of his active life in an environment where heat, moisture, and in some special cases, injurious elements are constantly evolved by the process of manufacture. These conditions are to some extent responsible for the quantity and quality of output and for the general efficiency of the plant.

There are several references in the literature to laboratory tests involving temperature and humidity and their resultant effect on work level efficiency. The Industrial Fatigue Board of England, in a report of its extensive investigation on the fatigue and efficiency of industrial workers, states that for temperatures under 40°F the hourly output was 10 percent above normal. Conversely a rise in temperature was followed by a decrease in efficiency, and for an external temperature of 65°F, the hourly output was 10 percent below normal.

In a report of the importance of temperature and humidity to physical work the New York State Commission on Ventilation states that men perform 28 percent less physical work in a temperature of 86°F with 80 percent humidity than in one of 68°F and 50 percent relative humidity. An estimate of the daily loss in output in an average size industrial plant operating at an efficiency of 70 percent will reveal the financial loss (9).

Experience with air conditioning in many countries has shown that with relative humidities of 40-70 percent, men doing light work indoors can do so with maximum comfort in air temperatures above 60°F, and below 76°F. The optimum actually prescribed will vary in different countries, according to the clothing worn, the degree of physical activity, the average conditions out of doors and the type of heating and ventilation used. It is agreed that very high and very low degrees of relative humidity are to be avoided—high values because they lead to a feeling of oppression and low values as they eventually produce restlessness and irritability.

The differences in the optimum conditions in different countries may be illustrated by a comparison of the recommendations for indoor air conditioning made in England and in the United States. With medium relative humidity the summer optimum is 66°F in England and 76°F in the United States; the winter optimum is 62-64°F in England and 72°F in the United States (3).

FACTS AND DEFINITIONS

The temperature of the deep tissues of the human body is said to be 98.4°F in normal conditions. It is generally stated that a rise of body temparature to 107°F is likely to be fatal, but there is no equally definite range of fall of temperature which can be regarded as fatal. Heat is continually being generated within the body, even during sleep, as a result of the chemical processes associated with breathing, digestion and physical effort (metabolism). The heat is conducted to the skin partly by the normal conducting power of the body tissues, partly by the bloodstream, and is dissipated from the skin to the environment. Heat cannot be conducted to the skin unless the temperature of the skin is lower than that of the deeper tissues of the body. Observations show that the skin temperature varies over different parts of the body, being lowest of all over the feet and next lowest over the hands.

When the body is cooled at too rapid a rate the following reactions occur: 1. the skin temperature falls, 2. there is an onset of shivering, an involuntary effort to increase the internal production of heat by muscular action, 3. the adrenal and thyroid glands discharge fluids which accelerate the metabolic generation of heat. When the body is cooled at an insufficient rate the sweat glands discharge sweat on to the surface of the skin, where it evaporates and in so doing takes heat from the body. Heat is dissipated from the skin by radiation, convection and by evaporation (10).

[1] Based on Paper No. 5 on *Topics in Applied Meteorology* from the Meteorological Laboratory, University of Michigan, Ann Arbor, Michigan.

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Effective temperature is a term used quite frequently in the literature and is essentially nothing more than an arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body. The numerical scale value is that of the temperature of still, saturated air which would induce an identical sensation.

Metabolism, by means of its simplest definition, is the obtaining of energy from the food supply and is measured by heat produced within the body by the process of oxidation.

The fundamental thermodynamic process concerned with heat interchanges between the body and its environment is frequently described in the literature by the following equation (9):

$$M = \pm S + E \pm R \pm C$$

where

M = rate of metabolism and is always positive,
S = rate of storage and is plus or minus depending upon whether heat is being stored or depleted owing to a rise or fall in body temperature,
E = rate of evaporative heat loss and normally this is positive as the dew point of the air is below body temperature,
R = rate of radiative heat loss or gain, and is positive when the body surface temperature is above that of the surrounding walls or ambient air, and
C = rate of convective heat loss or gain, and its sign is determined in the above description outlined for radiation.

TEST CHAMBER EXPERIMENTS

Yaglou and McConnell (7) experimented with subjects doing measurable amounts of work at a constant rate in still and in moving air of various temperatures and humidities. Half of the subjects worked in one chamber at still air and the other half worked in another chamber maintained at the same temperature and humidity as the first, but with an air velocity of 350 ft. per min.

The work performed consisted in raising a known weight attached to a rope, the latter passing over a pulley and provided with a suitable handle at the other end. The weights were so adjusted that a force of 40 lb. was required to overcome friction of rope and weight guides, and raise the weight at a uniform rate. The distance through which the weights were raised was fixed to 5 ft., so that each pull presented 200 ft.-lb. of work done. Each subject was required to raise the weight 75 times in 5 min. He then rested for the next 5 min. and repeated the work alternately thereafter until compelled to leave the chamber either because of fatigue or because of the severity of exposure. At the lower temperatures the subjects were not required to remain in the test chamber longer than 3 hr. The results of the test are summarized in Figure 1 (7).

In another controlled experiment by Eichna (5), a

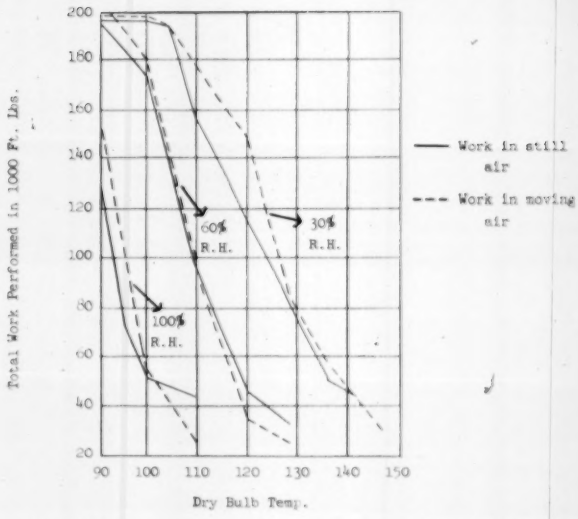

FIG. 1. Variations of Measurable Work Performed During Controlled Conditions of Temperature, Humidity and Air Movement.

series of tests were conducted on garrison-trained soldiers marching at the rate of 3 mph, around a track of 77 ft. diameter and carrying a 20 lb. pack. The conditions of temperature and humidity were carefully controlled, and regular meteorological observations were made during the test. The wall temperatures were approximately the same as the air temperatures, though at air temperatures of 120°F it was thought to be 7-9°F lower than the air temperature.

The environments, in which tests were made were divided into three categories:

1. Easy environments, in which the men completed four hours marching without complaint.
2. Difficult environments, in which the men completed four hours marching but with many complaints and with much, much effort, and had to be urged to continue.
3. Impossible environments in which the group of men as a unit had to be goaded to maintain their working rate. About one third of the men lasted out two hours and usually only two or three men finished four hours of marching. Undesirable symptoms developed after 30 min., and progressed rapidly.

Figure 2 shows the lines giving a close fit to the conditions of the trials which fell into three categories. The outsanding feature of this diagram is the narrow range of wet bulb temperature in which the transition from easy to impossible takes place. Thus in saturated air, 92°F was classed as an "easy" environment, 94°F as "difficult" and 96°F as "impossible" (5).

It is a matter of common experience that one's inclination for mental effort may diminish in very hot environments. Mackworth carried out experiments to test this hypothesis. He studied the performance of eleven physically fit wireless telegraphy operators. Before the main tests the men were acclimatized by exposure to effective

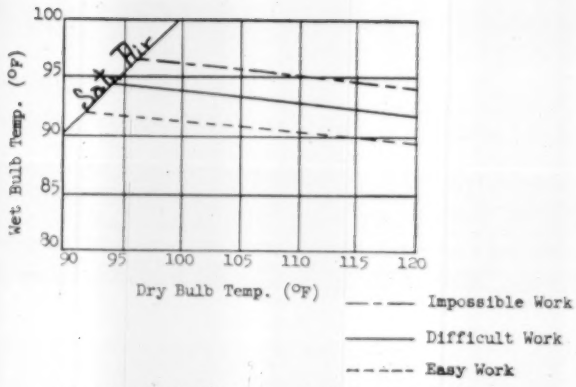

FIG. 2. Relationship between Endurance Tests and Temperature Environments.

temperatures of from 87.5° to 95°F for 3 hr. a day 5 or 6 days a week over a period of 7 to 11 weeks. On the test days work was done for 3 hr., during which period nine messages each of 250 groups were transmitted at a speed of 22 words per min.

The air velocity was 100 ft. per min. throughout the tests, and the dry bulb temperature ranged between 85°F and 105°F, with the wet bulb temperature in each instance 10° below the dry bulb. These conditions represented effective temperatures of from 79° to 97°F.

Hot and moist atmosphere seriously impaired the accuracy with which these trained men could record the Morse messages. The average numbers of errors per subject per hour are shown in Table 1.

TABLE 1

Variation of Mental Adaptness with Temperature and Humidity

	Average Number of Mistakes Per Hour				
Dry Bulb (deg. F)	85	90	95	100	105
Wet Bulb (deg. F)	75	80	85	90	95
Effective Temperature	79	83	88	92	97
Mistakes per subject per hour	12.0	11.5	15.3	17.3	94.7

The reduction in accuracy when the effective temperature reached 88°F was statistically significant. The data given are the averages for all the subjects.

It is noteworthy that the exceptionally competent members of this group were less affected by the difficult atmospheric conditions than men regarded as very good operators, while men of ordinary ability showed the greatest deterioration of all. This is an interesting point because industrial fatigue studies indicate that under difficult conditions the more competent workers show less signs of fatigue than their fellow workers.

There were no signs of cumulative effects from day to day, but during a 3 hr. period the number of errors per hour rose progressively. On the whole, errors were twice as numerous in the second hour as in the first, and three times as numerous in the third hour (1).

The New York State Commission on Ventilation conducted controlled chamber tests to evaluate the effects of various stimulus on physical work performed. Groups of subjects were kept in the experimental chamber under four different conditions: 68°F with a fresh-air supply of 45 cfm per person; 68°F with stagnant air; 75°F with the fresh air fans on; and 75°F with stagnant air. In all cases relative humidity was between 49 and 54 percent. For two work periods of 1 hr., each of the subjects lifted a 5 lb. iron dumb-bell through a distance of 2.25 ft. as many times as he chose, with no urging from the observer, but with a small additional incentive bonus on the basis of the amount of work performed, as recorded by an automatic counter. Thus a modest piece-work incentive was supplied. The results, for four subjects over a period of 20 days is summarized in Table 2.

TABLE 2

Effects of Different Stimulus on the Amount of Physical Work Performed

	Cool Temp. Plus Air	Cool Temp. Stag. Air	Warm Temp. Plus Air	Warm Temp. Stag. Air
Ft.-lb. work	26,711	24,359	22,771	20,481

The maximum figure of 26,711 ft.-lb. was reduced 9 percent in the cool stagnant air, 15 percent in the warm air with air movement, and 23 percent in the warm stagnant air. It is a striking fact that an increase in air temperature from 68°F to 75°F plus elimination of air movement should cut production down by nearly one quarter (even with moderately low relative humidity) (8).

EXPERIMENTS WITH PRODUCTION PERSONNEL

Unfortunately there is very little information in the literature regarding the use of air conditioning in production areas of industrial organizations. Vernon (1) showed a definite need for such considerations in his analysis of the seasonal trend in efficiency for the tin plate rolling mills in England. The analysis showed in heavy work, especially when it involves exposure to high temperature, output undergoes a consistent seasonal variation. It is generally greatest in winter, least in summer and intermediate between the two in spring and autumn. The variations in output noted by these observers are shown in Table 3.

Vernon showed the close relationship between the external temperature and the output from tinplate rolling mills. When the relative rate of output was plotted on the same diagram as the mean monthly temperatures, with the latter being shown on a reversed scale, the two curves were found to follow practically the same course. The

TABLE 3

Seasonal Trends in the Productivity of Tin Plate Workers

Operations	Relative Output		
	Dec.–Mar.	Spring–Autumn	June–Sept.
Men charging blast furnaces	105.0	106.5	88.5
Open hearth steel melters-Works	107.7	102.0	92.2
Open hearth steel melters-Works	85.7	85.1	84.8
Open hearth steel melters-Works	102.5	100.5	97.2
Open hearth steel melters-Works	102.5	104.6	102.8
Rolling mill men	107.0	106.5	107.0
Rolling mill men	124.0	118.0	111.0
Rolling mill men	105.2	98.4	96.5
Men puddling wrought iron	104.7	102.2	96.0
Tinplate mill men	103.3	99.9	96.9
Glass bottle making	101.7	99.6	98.7

output in August was about 10 percent less than that in December and January.

In factories devoted to hot industry, ventilation is of much importance. Copious supplies of cool air reduces the temperature, and the beneficial effect of this lowered temperature is enhanced by the additional air movement. Vernon found that in the best ventilated factories the output in summer was only 3 percent less than in winter, while in the worst ventilated factory it was over 13 percent less. Vernon further estimated that in the worst ventilated factory the output on the hottest days was probably 30 percent less than in the coldest weather.

An industrial investigation of working efficiency in the mining industry was conducted by Vernon, Bedford and Warner (1). As an index of the rate of working the time taken to fill a tram with coal was measured, and the amount of time taken in short rests noted. From these data it is possible to calculate approximately the relative efficiency of men working in different places.

The dry-bulb temperature observed varied from 63°F to 89°F and the wet-bulb temperature ranged from 59° F to 82°F. In the hotter working places the time taken for resting and the time required to load a tram of coal both increased, and it was calculated that the working efficiency of the men in the hottest places was only 59 percent of that of the men working in the coolest places.

Today there are several organizations that have their production personnel in air conditioned plants but very little specific information is available as to their improved working efficiency. However, the Reynolds Metals Company in Phoenix, Arizona has forwarded information concerning their plant-wide ventilating and cooling system.

The Reynolds Phoenix plant operation consists of melting, casting, extruding, heat treating, finishing, and drawing aluminum alloys into a multitude of different sections. The plant consists of approximately 1,500,000 sq. ft. of floor area and is air conditioned with 34 Carrier air washers of various sizes. The washers recirculate 25,300 gal. per min. of spray water while moving 2,500,000 cfm of air. The air washing results in a cooling effect equivalent to about 5,600 tons of refrigeration. The installed cooling capacity of the units will handle 123 percent of the plant's internal load and will do an adequate job of cooling at a reasonable cost, so long as the humidity remains fairly low.

An estimate of the work efficiency is difficult to determine in that the plant has never operated in the summer without using the cooling system. The Chief Engineer for the Phoenix plant estimates that without the use of the ventilating and cooling system the over-all efficiency would drop 25 percent and that the quality of the finished product would also undoubtedly suffer (6).

CONSIDERATIONS IN EVALUATING WORK EFFICIENCY

It has been generally assumed that there is a characteristic diurnal curve representing the course of efficiency during the waging hours for the average person. However, this isn't the true situation. To determine a diurnal efficiency curve we must consider the age of the subjects, their occupation and their own habits, particularly with reference to times of sleeping, eating and peak loads of work demanded by the requirements of their jobs. For example, in school children and adults who perform mental work there is a low point at the beginning of the day, a rise until noon, a slump around mealtime, then a rise in the afternoon followed by a drop in the late evening. On the other hand, tests of physical strength, speed of movement and the like show a steadily increasing efficiency throughout the day into late afternoon, then a subsequent drop.

The weekly trends in efficiency are determined by the habits of the particular culture to which a person belongs. Thus we find one type of efficiency curve for the Russian workmen who have no Sunday holiday and whose week differs in length from ours, and an entirely different curve for American workmen. The weekly English industrial curve commences at a low level on Monday, rises during Tuesday and Wednesday, reaches a peak at midweek, then drops sharply Thursday and recovers partially during Friday and Saturday.

Weather conditions are found to have an influence on people's moods and in turn their efficiency. Atmospheric conditions, primarily barometric pressure, also effect efficiency. When the barometer rises, nervousness and irritability increase and ability to concentrate declines (2).

The two classic examples of evaluating work efficiency are the early experiments with lighting and sound dampening. Improved lighting was put into one plant and production went up 25 percent. The lighting was reduced to its original level and production stayed at its new high. The lighting was further reduced below its original intensity and yet production still remained at its high level.

The same situation developed with respect to noise control with another company. The company proposed reducing the noise level in its computer office and installed sound dampening materials. Production and work efficiency immediately improved. Unfortunately someone in

the organization suggested an experiment to put board panels over the sound dampening material. The result was that the noise level hit a new high in the office but efficiency still remained at its new high point.

Both of these cases are examples of personnel reaction to management interest in their comfort and well being and not an indication of improved efficiency due to physical changes in the work atmosphere.

CONCLUSIONS

The aforementioned section on the evaluation of work efficiency is by no means an implication that air conditioning has not improved work efficiency. The author is definitely convinced that air conditioning has and can improve working efficiency. The only question is, how much improvement can be attributed directly to the air conditioning and what percent is due to other causes and effects. However, the breakdown of the improved efficiency is an academic question and is of little concern to the industrial organizations whose production costs have been reduced and the work efficiency set at a new high.

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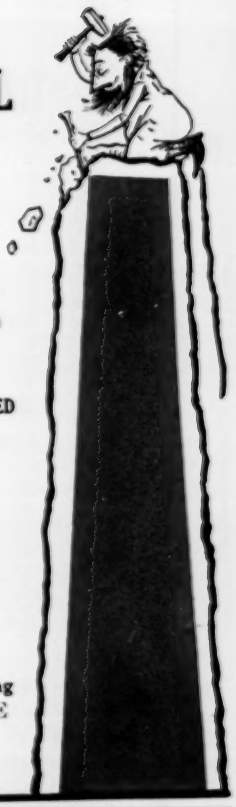

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Computing Machines: Rent or Buy?

by **WILLIAM HAYNES STARBUCK**

Graduate School of Industrial Administration, Carnegie Institute of Technology

DURING the nine years that electronic computers have been commercially available, the majority of users, by far, have chosen to rent their machines. These decisions do not necessarily mean that renting was more economical than buying, however, since there have been nonfinancial pressures which would lead the users to choose a rental plan.

One such pressure arises from the fact that computers are a new and rather revolutionary type of investment, Particularly in the beginning, there was little information on which the user could base a decision to buy. The capabilities of computers were not fully understood even by the engineers who designed them, so it was difficult to judge what value the machines would be to their users, or how soon a given machine would become obsolete in respect to newer models. Moreover, few customers had any experience in the operation of electronic machines of the size and complexity of large computers. With an investment of tens of thousands of dollars involved, and no knowledge about how useful the investment would be, what life span could be expected, or what costs would be incurred, it was natural for users to shy away from the risks of ownership.

A second type of pressure in favor of rentals was exerted by the computer manufacturers themselves. IBM has offered machines only on a rental basis, so that the user who definitely wanted an IBM computer was forced to rent. Sperry Rand, while offering to sell, has also encouraged its customers to rent.

However, it seems likely that in the future more users will consider buying their machines. Although the application of computers is still a rather vaguely understood (and opinionated) field, some comprehension of what the machines can do and how they should be used is beginning to emerge. In addition, the Consent Decree of January 1956 which forces IBM to offer their machines for sale will extend the rent-or-buy choice to a wider selection of machines. As a result, many firms are finding it necessary to re-examine the rent-or-buy decision with an eye toward the special problems posed by computing machines.

This report is intended to do just that: to consider the rent-or-buy decision as it applies to computing machines, and to suggest a method for making the decision. Moreover, it will be shown that the same basic calculation is applicable to a choice between different machines.

The method which is suggested is novel in some respects. First, the MAPI method is used to estimate the machine's life expectancy for several possible obsolescence rates (1). Second, probability theory is applied to select the most desirable life span. And third, cost estimates are made for each period of the machine's expected life. It is hoped that this method will be found useful in a number of applications where rapidly evolving technology and large expenditures make the rent-or-buy decision critical.

For purposes of discussion, the balance of this report is divided into four sections. Part 1 will consider the general nature of the rent-or-buy decision; part 2 will explain the life calculation; part 3 will explain the remainder of the calculation; and part 4 will point out how the method can be applied to a choice between different machines. Three basic assumptions are made:

1. That the customer knows what kinds of machines are available and how well they will do his job.
2. That the customer knows for what purposes the machine will be used.
3. That the customer intends to make no modifications of the machine which, by being unacceptable to the manufacturer, would make purchasing imperative.

1. THE RENT-OR-BUY DECISION

All rent-or-buy decisions are basically the same. The purchase option can be described by an initial investment, I_p, and a series of periodic costs, C_p; and similarly, the rental option can be described by an initial investment, I_r, and a series of periodic costs, C_r. The difference between the two options is that I_p is greater than I_r, while C_p is less than C_r.

In order to compare the two choices, the four variables can be reduced to two by subtracting

$$I_p - I_r = I_d$$
$$C_r - C_p = C_d$$

I_d represents the differential investment which would be required if the machine were purchased, and C_d represents the series of differential costs which must be paid if the machine is rented.

The central question in the rent-or-buy decision is: which option, purchase or rental, will minimize the customer's total cost? In light of the above statements, this decision becomes a choice between I_d and the series C_d. If he buys, the customer will have to make an additional initial expenditure I_d; if he rents, he can replace this initial expenditure by a series of future payments C_d.

At this point, the decision requires two more pieces of

information: the interest rate which is acceptable as a return on I_d, and the life of the machine.

Estimation of the interest rate is generally conceded to be a straight forward (if difficult) problem. At least the primary question is easily understood: what rate of return could be obtained if the funds are invested elsewhere? The difficulty arises because most customers shy away from the risks of owning an asset which is subject to rapid technological development. Consequently, they raise the interest rate an arbitrary amount, hoping to compensate for these risks.

Frankly, this procedure is not to be recommended. It simply adds an unknown error to the calculation. There is a much more logical solution to the problem: estimate the risks involved. The final result may be the same, but assessing the risks in dollars and cents will force the decision-maker to think rationally about probabilities. Let us assume, for example, that the customer is afraid that he will have to make an additional capital outlay in three years, an outlay which the manufacturer would make if the machine were rented. He should:

1. Estimate the amount.
2. Find the present worth of this amount.
3. Estimate the probability of the need arising.
4. Multiply the present worth by the probability to obtain a mathematical expectation.
5. Add the expectation to I_p.

If in addition, the period of time is in question, a probability distribution can be set up for various possible time periods.

The life of a computing machine is primarily its technological life. Occasionally the physical life of an investment becomes important when the machine is expected to wear out before it becomes technologically obsolete, but the best estimates at this stage of computer development indicate that computers will have a physical life that is many times their technological life. In fact, due to the heavy use of preventive maintenance, maintenance costs should rise so gradually that even they should not seriously affect the machine life.

In view of this emphasis on technological obsolescence, it seems that the MAPI method will be the most productive approach to the life estimate. This method is designed to cope with the technological problem, and it offers the advantage of allowing the customer to estimate what life span will maximize the return on his investment.

One more comment should be added before proceeding to part 2: a computer installation is not one machine, but a group of separate units which function together. Some of these units are primarily electronic, some are primarily electromechanical, and some are primarily mechanical. The maintenance costs and obsolescence rates will vary depending upon the type of unit in question. Consequently, the decision to rent-or-buy should be made for each unit individually. The manufacturers' sales offices report that although they have never encountered the situation, they are willing to sell part of an installation and rent the remainder.

2. THE LIFE CALCULATION

Once the interest rate has been selected, the next step in the calculation is an estimate of the machine's life span. As was mentioned previously, the approach which is recommended is an adaptation of the MAPI method. The objective of this method is to select that life span which will minimize the equivalent uniform annual cost of the machine.

The total cost of keeping a machine for an additional period of time is the sum of:

1. The loss in salvage value over that period.
2. The interest on the salvage value at the start of the period.
3. The loss over that period due to obsolescence.

This latter figure is the result of comparing the cost of operating the machine owned with the cost of operating the most modern replacement. In the MAPI publications it is referred to as "operating inferiority," and the rate at which it increases is the "inferiority gradient." This nomenclature will be used here.

ESTIMATING THE INFERIORITY GRADIENT

The usual assumption which is made about operating inferiority is that the inferiority gradient is a constant. This assumption is not necessary, in as much as the calculation can be based on any appropriate equation; but on "a priori" grounds there are two reasons for believing that the inferiority gradient of a computer will tend to be constant. First, the computer market is dominated by two manufacturers who, because of the preponderance of rentals, own nearly all of the machines. These manufacturers cannot afford to introduce technological improvements rapidly because they would render their own assets obsolete; neither can they afford to introduce new products irregularly because this would disrupt production and make the modernization of old machines difficult. Second, the availability of modernization equipment will also stabilize the inferiority gradient. It means that new equipment will be compatible with existing equipment, and that any revolutionary developments will be accompanied by modification accessories for existing equipment.

From the customer's viewpoint, the efficiency of a computer is simply how cheaply it will perform his particular calculations. Since each customer uses the machine for a different set of problems and operates it a different number of hours, changes in operating inferiority must be calculated for each customer individually. One way to handle this calculation would be to derive a function which relates total machine operating time to the speed with which the machine performs component operations like additions, multiplications, and transfers. This method will give reasonable estimates provided that the programs are assumed to be constant. However, it will

never give the optimum answer because each new machine offers a different selection of operations, requires more or less highly skilled personnel, and offers special accessories. The ideal solution would be for the manufacturers to publish more complete information on each new machine—say, operating times for a selection of typical problems, which figures could be reinterpreted by the customer in the light of his own needs. Perhaps some day the beleaguered accountants will rise up and demand this service, but until then more approximate methods will have to be used.

In general one expects the graph of operating inferiority versus time to look something like Figure 1. It will not rise smoothly, but in erratic steps depending upon what new developments are brought out, when they are brought out, and what they cost. Needless to say, this complicates the calculation of the inferiority gradient. If the average gradient were the only problem, one could simply accumulate some data over a short period of time and then fit a straight line to these points and the origin. However, the life estimate is our basic objective, and the calculation of this figure requires more information than a short period of time can give.

The life estimate which is needed is not an engineering figure, but an accounting figure. If the machine becomes obsolete before the expected date, a decision to purchase may have been wrong; if the machine becomes obsolete after the expected date, a decision to rent may have been wrong. Consequently, the life expectancy figure which is used should balance out these two risks.

Because of the discontinuous form of the operating inferiority graph, the effective inferiority gradient at the end of the machine's life can take on a number of different values. Each of these possible values of the gradient has a different probability of occurrence. Values near the average will be most probable. It is necessary to know this distribution of probabilities in order to minimize the risk that the estimated machine life will result in a wrong decision.

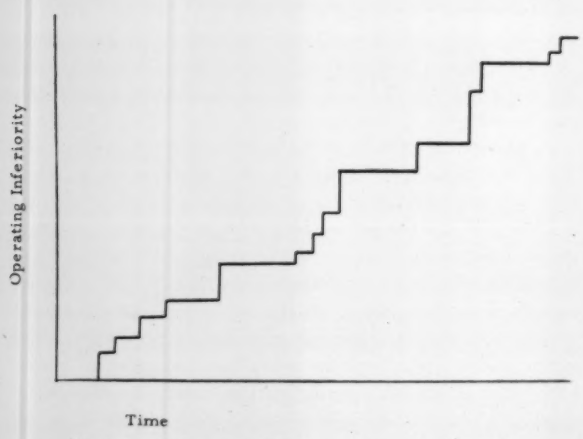

FIG. 1

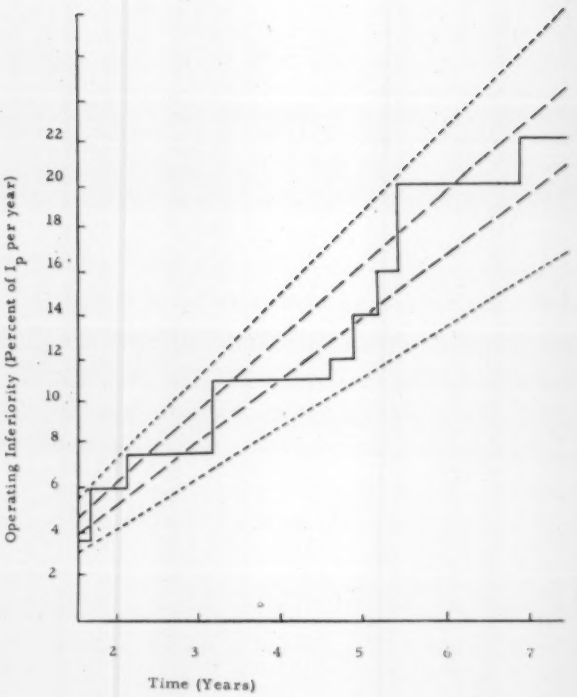

FIG. 2

Figure 2 illustrates a method for determining this distribution. The solid line is an enlargement of part of Figure 1. The horizontal axis has been assigned values of time in years; the vertical axis has been assigned values of operating inferiority as a percentage of I_p.

The first step is to subdivide the graph by lines representing constant values of the inferiority gradient, g. Any convenient number of subdivisions can be used, as long as all probable values of g are included. In this case, the graph was subdivided into three ranges by the lines representing

$g = (.0375)I_p$ (upper dot line)
$g = (.0325)I_p$ (upper dash line)
$g = (.0275)I_p$ (lower dash line)
$g = (.0225)I_p$ (lower dot line).

The second step is to find the percentage of the time that the operating inferiority fell into each range. For example, in this case the operating inferiority fell between the line for $g = (.0275)I_p$ and the line for $g = (.0225)I_p$ 23.2 percent of the time. These percentages will be taken as the probabilities that the effective inferiority gradient at the end of the machine's life will fall in each range.

The third step is to calculate the optimum machine life for the value of g which is the midpoint of each range. Thus, for the range between $g = (.0375)I_p$ and $g = (.0325)I_p$, one would calculate the machine life for $\bar{g} = (.0350)I_p$. Table 1 presents the values of the mid-

point gradients and the corresponding probabilities for each range in Figure 2.

TABLE 1

Range: From	$(.0225)I_p$	$(.0275)I_p$	$(.0325)I_p$
To	$(.0275)I_p$	$(.0325)I_p$	$(.0375)I_p$
Midpoint Gradient	$(.025)I_p$	$(.030)I_p$	$(.035)I_p$
Probability	.232	.540	.228

CALCULATION OF THE MACHINE LIFE

Given any value of g, the corresponding life figure can be found. Table 2 illustrates the calculation. The salvage value is taken as (\$100,000) · (.65)^t; these figures are listed in column A. The interest rate is 10.5% annually, giving rise to the figures in column B. And the operating inferiority for $g = (.03)I_p$ = \$3000, is tabulated in column D.

TABLE 2

Year	A Salvage Value (\$)	B Loss in Salvage Value (\$)	C Interest Cost (\$)	D Operating Inferiority (\$)	E Total Annual Cost (B C D) (\$)	F* Cumulative Present Worth (\$)	G* Uniform Annual Cost (\$)
0	100000			0			
1	65000	35000	10500	3000	48500	43900	48500
2	42250	22750	6830	6000	35580	73050	42400
3	27460	14790	4440	9000	28230	91950	36950
4	17850	9610	2880	12000	24490	107350	34250
5	11600	6250	1880	15000	23130	121350	32350
6	7540	4060	1220	18000	23280	134150	31200
7	4900	2640	790	21000	24430	146300	30500
8	3190	1710	520	24000	26230	158100	30150
9	2070	1120	340	27000	28460	169700	30000
10	1350	720	220	30000	30940	181100	30100
11	880	470	140	33000	33610	192300	30300
12	570	310	90	36000	36400	203300	30600
13	370	200	60	39000	39260	214000	30950
14	240	130	40	42000	42170	224400	31400
15	160	80	30	45000	45110	234500	31900

All figures are rounded to the nearest ten dollars.
* Slide rule accuracy.

When the figures in columns B, C, and D are added, one obtains the total annual cost for each year (column E). The next step is to find the uniform annual series which is equivalent to the total cost of keeping the machine for a given number of years. Thus, the uniform annual cost of keeping the machine for two years is: the sum of the present worth of \$48,500 and the present worth of \$35,580 all reduced to a uniform annual cost extending over two years, or \$42,400. The period of time which minimizes this uniform annual cost is the optimum life for the machine (given the inferiority gradient). In this case, the minimum uniform annual cost (the "adverse minimum") is achieved by keeping the machine for nine years, and so one can say that the optimum machine life for an inferiority gradient of \$3000 is nine years.

Table 3 illustrates the final machine life calculation. First, the calculation in Table 2 is repeated for the midpoint gradient in each range. (The results for the example are given in Table 3.) Second, the machine life for each midpoint gradient is multiplied by the probability for that range. And third, the products are summed to give the machine life. In this case, the estimated machine life is 9.05 years.

TABLE 3

Midpoint Gradient (\$)	Probability	Machine Life (Years)	Probability times Life (Years)
2500	.232	10.2	2.37
3000	.540	9.0	4.86
3500	.228	8.0	1.82
			9.05 Total

3. THE DECISION CALCULATION

Having arrived at estimates of the interest rate and the machine life, the next step is to compare I_d with C_d.

There are two methods which are normally used for making this comparison. One method converts I_d to a uniform annual series, and then compares this figure with the first term in the series C_d (that is, the differential cost in the first year). The second method finds the interest rate which will make I_d expressed as a uniform annual series, equal to the first term in the series C_d, and then compares this interest rate with the given interest rate.

Both of these methods have a common fault: they do not consider the variations in C_d. Clearly, the terms in C_d need not be constant over the machine's life. The manufacturer will raise his rental price to adjust for inflationary trends; maintenance costs will probably rise as the machine ages; a change from two shift operation to three shift operation may be planned.

Either of the two methods can be corrected for this fault by finding the total present worth of C_d and converting this figure to a uniform annual series. But there is no point in carrying the calculation so far. The present worth of C_d can be compared directly with I_d—no manipulation of uniform annual series or interest rates. If the present worth of C_d is greater than I_d, the customer should buy; if the present worth of C_d is less than I_d, the customer should rent.

It would be an exaggeration to say that the present worth method contributes anything new to the problem, since any of the three methods can be made equally general. The present worth method is preferable simply because it achieves the requisite generality with a minimum of calculation.

A few brief comments about the calculation of I_d and C_d:

1. The problem can be greatly simplified by considering only differential costs. Costs which are the same under either option will not affect the final result. For example, transportation costs can be ignored if the customer would have to pay them whether he rents or buys.
2. The figures should include any risk expectations and estimates of intangible values (like the advertising value of ownership).
3. C_d must include receipts as well as expenditures. The salvage value must be added at the end of the machine's life. If the

owner plans to rent the machine during times when it is not in use, these earnings must also be included.

4. The rent, of course, must be based on the expected number of shifts the machine will be in use. If an eventual increase in the number of shifts is planned, an increase in the rent must be allowed for.
5. Maintenance costs will not necessarily be proportional to operating time. A machine which is used forty hours might require ten hours of maintenance, while a machine which is used 160 hours might require only twenty hours of maintenance. Similarly, the maintenance costs of a primarily electronic machine will not increase a great deal as the machine ages, because the heavy use of preventive maintenance keeps the machine near its original operating condition and distributes the replacement of parts evenly over the life of the machine.
6. C_d must either be computed on a monthly basis or else adjusted for the timing of the expenditures. For example, monthly rents must be compounded to arrive at an annual figure.
7. C_d must be corrected for taxes and depreciation. If the marginal tax rate is r, the depreciation is D, and C_d before taxes is C_d'; then

$$C_d = (1 - r)C_d' + rD$$

Table 4 illustrates the calculation of the present worth of C_d. C_r is taken to be a constant \$37,850 annually. C_p is \$12,000 in the first year and increases by \$100 annually. The value of C_p in the tenth year includes a salvage value of \$2070, as was given in part 2. The depreciation is a straight line \$11,110, and the tax rate is 52%.

The answer which results is that the present worth of C_d is \$102,520.

I_p was assumed to be \$100,000. Let us further assume that I_r is \$1500, and that there is a risk expectation of \$500. Therefore, I_d is \$99,000. (\$100,000 − \$1500 + \$500).

Since the present worth of C_d is greater than I_d, the customer should buy rather than rent. He can expect to save \$3520.

TABLE 4

Year	C_r (\$)	C_p (\$)	C_d' (Before Tax)	Depreciation (\$)	C_d (After Tax)	Present Worth of C_d*
1	37850	12000	25850	11110	18180	16460
2	37850	12100	25750	11110	18140	14840
3	37850	12200	25650	11110	18090	13410
4	37850	12300	25550	11110	18040	12090
5	37850	12400	25450	11110	17990	10910
6	37850	12500	25350	11110	17940	9850
7	37850	12600	25250	11110	17900	8900
8	37850	12700	25150	11110	17850	8030
9	37850	12800	25050	11110	17800	7250
10	3290	−920	4210	10	2020	780
						\$102520 Total

All figures are rounded to the nearest ten dollars.
* Slide rule accuracy.

4. THE CHOICE BETWEEN DIFFERENT MACHINES

Theoretically every general purpose computer is a potential machine choice. They can all perform the basic operations which are necessary for calculation: add, subtract, compare, and various "housekeeping" operations. In this sense, all computers are equivalent . . . large or small, blue or green, round or square. The fundamental difference between machines is the speed with which they perform these basic operations. Some machines achieve high speeds by combining the basic operations into more or less complex special instructions, like multiply and divide; some machines achieve high speeds through advanced engineering techniques; and some machines achieve high speeds through sheer size. About the only general statement that can be made is that the faster a machine, the more it costs.

The task of the person who chooses a particular computer is one of balancing the cost of the machine against the amount of calculation to be done. Given certain limitations on the number and kinds of problems to be solved, and the time available for solving them, he must find the machine (or combination of machines) which will do the job most economically.

The procedure for making the rent-or-buy decision is also an excellent method for making this second type of decision. The first step is to make cost estimates on every possible machine choice. In principle this means information on all of the two dozen or so general purpose machines on the market, but a cursory cost survey should narrow the field considerably.

The second step is to make the rent-or-buy decision for each machine. This operation will mean that each machine is presented in the best possible light when it is compared with competitive machines.

The final step is a series of comparisons between machines. Two machines are compared, then the winner is compared with a third machine, and so forth. The basis for comparison is precisely the same as that in the rent-or-buy decision, only more complicated. The initial investments and series of future costs for each pair of machines will result in a differential investment and a differential series of costs. The major differences between this calculation and the rent-or-buy calculation are that:

1. Each machine will have a different life span.
2. More factors must be included in the cost estimates (e.g., the cost of floor space, the cost of the machine room, and the cost of supplies).

A second approach to this comparison between machines would be to find the present worth of the total cost of each machine, I_p plus C_p if the machine should be purchased, I_r plus C_r if the machine should be rented. Then the uniform annual costs of all machines can be compared simultaneously. This approach would save time if there are only three or four probable choices.

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Germany and Industrial Engineering

by **E. C. KEACHIE***

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THE startling figures on population are a good beginning to an attempt to understand industry, or any other phase of present day realities in Germany and Europe. The German Reich in 1937 comprised only sixty-nine million people in 180,000 square miles. Even allowing for totalitarianism's advantage in picking times and places to wage war, one may well ask what genius of technology and production, however misguided, could account for the amazing drive and resources thrown against the allies.

Today's West Germany has a population of some fifty million in a land area of 90,000 square miles compared with thirty-nine million in the same area in 1939, despite war losses. This is about half the size of California with fourteen million inhabitants. Fortunately Germany has a higher percentage of habitable terrain. Even so, West Germany's population density is over five hundred per square mile, ten times that of the U.S. and almost three times that of France. It has been growing, swelled by refugees, especially by those from former German territories, and from East Germany. From three thousand to five thousand a month find their way to the processing center in West Berlin.

Despite the migrations, East Germany still has about eighteen million so that together East and West Germany have about the same population as the pre-war Reich, on 75% of the land area. The remaining areas comprise West Berlin, East Berlin, the Saar, territories east of the Oder and Neisse Rivers, now under Poland, and northern East Prussia, now under the Soviets.

Since many refugees are the most capable and ambitious people, it is not surprising that refugees now comprise a significant part of the enterprise of West Germany and that many pre-war east zone companies have risen anew in the west. Sometimes they are competing with their "parents" since East Germany, too, is struggling for world markets. Despite the significance of East as well as West Germany, our discussion will now concern only the West, called simply "Germany."

For some time now Germany has been the leading nation of the West in output, reflected in the Gross National Product, with the sole exception of the United States. From an almost unmeasurably small production in the chaos of 1945, Germany has come back to this high point. Her currency, revalued in 1948, is now so strong as to be an embarrassment to others such as Britain and France and even to herself. While they have been bolstering their currency and raising interest rates to the neighborhood of 7 percent, Germany has encouraged imports as well as exports and cut its discount rate to 3½%. Not only is Germany producing consumer goods for herself at a modest but adequate level, enough to keep inflation in check, but she is exporting consumer goods and capital goods to many countries of the world. This is a far cry from the thoughts expressed by some of the Allies at the end of the war in regard to keeping her from ever again becoming an industrial power which might threaten war, but force her to develop such things as agriculture. One factor which has helped the German economy by keeping its costs low is, paradoxically, that she had no expense for any army up until 1956, except for the maintenance of occupation forces.

The German revival has often been called a "miracle." It certainly was not forecast in the very early post-war years. Generally it has been attributed first to hard work and to the currency reform which gave hard money. In addition, it should be noted that in part through our influence Germany took steps toward a freer enterprise economy, which was a change from the past and in advance of developments in most other Western European countries. Controls over prices were thrown out early, in 1948. Government operated on a basis of tight money and balanced budgets in order to give private business greater incentive. In passing, though, it should be noted that the German federal and state governments took on the tremendous burden of social security for the many disabled and those displaced from their home location or employment. The war's imprint is forcibly presented in population graphs showing the dearth of men in the 30-50 year groups, which accounts for the shortage of engineers and managers between these ages.

INDUSTRIAL ENGINEERING—GENERAL

Few things in America are as thoroughly organized and as smoothly carried on as many of the typical activities of people in Germany. For example, the program for a dinner meeting of an engineering society is set

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well in advance and the notice of the meeting is sent to the member. But instead of a reply card to the Secretary, with its twin hazards of promisers who don't show and showers who don't promise, the Deutsche Mitglieder (member) is advised to make payment directly to the Society's bank or to the Post Office, giving the Society's account number, a stated time in advance of the meeting. The secretary can then check and collect the paid attendance before the meeting and have "alles in ordnung" with nothing to do but shake hands and introduce people as they arrive. Promisers who don't show have already settled their debt. Surprise showers had better have a good story. They usually do, because the well-ordered and busy German would lose face by admitting to such a lack of pre-planning of one's precious time.

The great difference between Industrial Engineering as practiced in Germany and in America is illustrated by saying that while we are "scientific," they are better characterized as "systematic." You may remember that "systematic" was a characterization given by Taylor to the best of previous management, that at least a standardization had been achieved even though it was not at the optimum level. Taylor's improvement, of course, was true standardization of the one best way, "scientific" management. There is enough truth in this generalization to apply it to Germany.

The world knows Germany's reputation in science, especially from the end of the last century when she was a mecca for scholars from many other countries through her development of both theoretical and applied science. In both consumer products and industrial projects up to complete steel mills, she is again today active in world markets. Phenomenally, her export sales of industrial goods have increased 300% in the last five years! The stereotype of German industry emphasizes, in addition to careful and inventive engineering, a related tremendous ability and willingness to take pains in execution, so that precision workmanship is a hallmark of her production, and this stereotype is certainly still largely valid. One has only to look at some of the die casting, instrumentation, industrial photography, and other things where these characteristics can become evident. However, an important exception will be noted when we look at specific areas of Industrial Engineering.

Business organization in Germany is effective but is apt to emphasize tight line control and a dogmatic approach to communication. Not for nothing is heart disease known as "die manager-krankheit"—this stems, at least in part, from lack of delegation. This of course is a natural result of tradition and the practice of closely held ownership with its corollaries of family succession, emphasis on control of a "satisfactory" segment of the market, and cost reduction for the purpose of increasing profits on current volume rather than as a basis for increased profits through lower prices and wider markets. Our free enterprise corollaries of higher wages and better living standards are correspondingly neglected. To the extent that these statements contradict the above-mentioned ideas of Germany as an exponent of free enterprise and anti-cartelization, they are true. Relatively, of course, she has come a long way toward free enterprise and is more representative of free enterprise than most other European countries. It would be too much to expect that the old order would change completely, especially since its adherents are still numerous and potent, and some of its basic conditions for survival are still there.

Like many other industrialists of Europe, those of Germany know more than they apply in their own jobs of Industrial Engineering and management. Of course this could even be said of our own people. We have already noted Germany's excellence in scientific development and applied research on machines and processes, including frontier areas such as in the ceramics industry, as well as traditional craftsmanship. A capacity for taking pains as well as hard work is clearly evident. Managerially system and order are revered, except perhaps in the executive's own work. Since top management is few in number, with less delegation than in the U.S., staff work is more restricted and professions like Industrial Engineering have more difficulty in gaining recognition.

DESIGN—STANDARDIZATION

Product design is a specific area where Germans are often outstanding, at least in so far as design for function and maintenance is concerned. They know about standardization and simplification but they like to claim that it is necessary to have great variety to satisfy their various markets—in many cases because their markets are in different countries having different buying habits. The American answer to this of course is to make an optimum standardization that can be produced so cheaply that the market is forced to accept it. This lack of standardization is typical of much European production, although the exceptions such as Volkswagen, Olivetti and Britain's Joseph Lucas are prominent because they represent the most successful high-volume products. The D I N (German Standards Association) and R K V (Management Engineering Association) have been fighting an uphill battle in favor of standardization in Germany and of course, to some extent, standarization naturally does vary with the market as indicated above.

LAYOUT AND MATERIALS HANDLING

In line with the above, layout tends more to process than line but often very effective use is made of basic principles by having short lines for both process and assembly, where volume warrants, and by having lines set up so as to be readily changed.

When it comes to materials handling it is probably a fair generalization to say that there is less mechanization and more hand lifting than here. In one plant making piston rings almost all employees were men, operat-

ing machines, but the few women were doing heavy lifting of boxes of parts over their heads! On the other hand, the development of locomotives, cranes, conveyors, aerial tramways, and other materials handling equipment has reached a high state. This is apparent particularly in such shows as the Hanover Industrial Fair with its spectacular displays of operating machines. To make a partial summary at this point, one may say that the Germans know how to apply scientific management. "Rationalisierung" is an old familiar concept. They are interested even to the extent of visiting the U. S., but they use the same cliché that we do: "doesn't apply to our business," in order to justify the present state of inapplication. Naturally, other important factors are involved, such as the relationship of ownership and management and the fact that industry is in the process of being rebuilt from its bomb damage, and foreign "liberation" of tools.

SAFETY

Safety seems to get far less overt attention than it does here, in spite of the fact that Workmen's Compensation was begun in 1877 under Bismarck. There is a tendency to presume that employees should look out for themselves, avoid open manholes and not put their hands in moving machinery. However in the light industries observed they were quite progressive in such things as punch press guarding and automatic safety switches to prevent operation when hands may be under a press. Housekeeping in new plants seemed on about a par with the United States but in older plants there was considerable variation, probably more than here. In part this was due to attempting to operate above normal capacity in incompletely rebuilt plants, coupled with the previously noted variation in design that made for many different parts lying around on the floor.

PRODUCTION CONTROL

Production control including near-term planning, routing, scheduling, and dispatching seemed to be highly systematized at an idea level of good "scientific management" but without any evidence of newer mathematical programming techniques. Considerable use was made of Gantt Charts and one commercially available form was often noted which used ball bearings in vertical slots to indicate, for example, machine loading.

NEWER TECHNIQUES

Probably a natural corollary to the foreigners' lag in utilizing Industrial Engineering in the well defined areas above is an even more pronounced lag in using the newer techniques, with of course some notable exceptions. Operations Research techniques were not observed by the author in any plant. Most managers did not know much if anything about them. On the other hand, there was, particularly in the state and federal government, statistical and banking offices, considerable use of modern electronic data processing and office automation equipment. Further, the actual development of computers has been fostered in Europe; and at Darmstadt there is an important, long-standing applied mathematics institute which is developing the computer "DERA." This again supports the idea that the Germans are inventive, painstaking and systematic first, and that organization and application involving methods changes lag more than here.

QUALITY CONTROL

Statistical quality control seems to be prominently absent. This can be seen even in noting the wide quality variations in some products such as milk bottles, as well as by observation of production methods and talks with engineers and managers. Sometimes they will say that they use statistical quality control when they really mean only an arbitrary sampling, of say 10%, in inspection. This indicates that statistical quality control is even less applied than other aspects of Industrial Engineering, particularly because it is relatively little known. This appears a curious contradiction of the German penchant for applying science and mathematics and development of system. In the "Industrial Engineering" curriculum at Darmstadt the only statistics taught was the business administration type emphasizing trend lines and seasonal variation analysis, primarily with respect to marketing problems, when in the same building is one of the leading applied mathematics departments in Europe. Even though these ideas were brought out tactfully, yet as strongly as possible, there was no indication of a desire for change in the near future.

METHODS AND STANDARDS

No discussion of Industrial Engineering would be complete without some mention of the pace of work and REFA, the professional society most nearly approximating AIIE.

The pace of work, to generalize broadly from a limited sample, appeared steady but not fast, although quite variable between plants, compared with ours. In the photographic equipment industry, four different plants were visited and pace differences were apparent in them. The company with the highest priced product, and apparently the biggest backlog, seemed in no hurry at all. Two close competitors had noticeably different speeds of manual work. Interestingly, the slower one was in the process of buying up the faster one at the time. The fourth company showed strong influence of American know-how. Its operations were more rationalized, and as might be expected, pace exceeded the other three and appeared quite comparable to good practice here.

The REFA, with headquarters at Darmstadt, has a large membership of engineers and a vigorous journal, *Nachrichten*, "Zeitschrift für Arbeitstudien" (work-study). The Society is organized both geographically and by industries, so that a factory manager may readily

call in a consulting member who, besides experience, has access to special studies that have been made of the industry. In fact, the head of REFA, Prof. Dr. Ing. Erwin Bramisfeld, paid us the compliment of telling me "We have the organization, but you have the information!" They are especially interested in the setting of standards, as the basis for incentive wages. Methods improvement is secondary to this.

However, when one considers the various professional efforts that are being conducted by REFA, RKV and others doing research in the area, such as the Max Planck Institut für Arbeits Physiologie in Dortmund, their contributions to our field may yet increase the flow of ideas from east to west.

AUTOMATION AND ATTITUDES

One notable contrast with the usual Industrial Engineering lag was in the area of automation. A great interest on the part of many people, including some managers, was apparent. They wanted to learn more about automation, especially its social and economic effects. To understand this wide and intense interest one has only to reflect on past disasters felt by many of these people as a result of broad causes such as inflation and world trade conditions. Not having been educated to free enterprise capitalism to the point of really believing in the idea that more efficient production eventually creates more jobs than it kills, the people look on automation as a possible Frankenstein. Nonetheless, there are in Germany a few excellent applications of automation as well as other recent developments such as the use of computers, printed circuits, and advanced design in machine tools and their programming.

To help understand attitudes toward technological change one must appreciate the tremendous security consciousness of the Germans, and of most Europeans. Social security itself was begun in Germany in 1888 under Bismarck, in marked contrast to our depression-inspired measures of 1935. German labor looks on itself as having far more to gain by broad political action and security of status than by continual pressure for better wages and hours, although these too have begun to come to the fore with the rise in employment and labor scarcity. The recent war injured are covered by disability pensions paid for by the state, and industry is required to hire a certain percentage of them.

Labor is less mobile and more inclined to follow a single occupation than in the United States; mobility within organizations is less. Consequently, automation's threat to wipe out occupations seems more serious than here. The whole philosophy in Europe is, and has been for years, far more concerned with the dread of enslavement of man by the machine than in our country. Here we are less afraid of the machine, perhaps like the old story about the worker who was asked if he was afraid of work and replied, "No, I just lay down beside it and go to sleep."

PLANT INVESTMENT

A principal aspect of plant investment practice is the difference between countries caused by different relationships between labor and equipment costs. Some equipment that would pay in the United States would not pay in Germany, since her labor rates are roughly only one third of ours. In addition to this, and other sidelights already given on plant investment, there are complicating factors which make the situation different from ours.

SUMMARY

As a rough summary of these somewhat diverse ideas one may say that because of the basic factors of lack of standardization and high development, more intensive applications of Industrial Engineering as illustrated by automation are likely to be slower in actual development than its man in the street either fears or hopes. However, even automation is already a fact in parts of some industries, such as in the large (25,000 workers) Opel automobile works (GMC) at Rüsselsheim, where American leadership is definitely implemented.

An amusing sidelight on the mental conflicts caused by a changing world is the attitude of the "composite" German automobile buyer. The U. S. policy of "planned obsolescence" reflected in the annual styling changes as well as worth while improvements, is resisted like the devil but likewise strongly attracts him. This is in spite of the daily evidence of virtue in the form of a Volkswagen, little changed since Hitler's time, with its obvious advantages of low depreciation and low maintenance costs. On the other hand, the German recognizes these savings as the result of standardization which otherwise is often sneered at as an American degeneration. In fact, one evidence of the much vaunted "American materialism" is our use of standardized products. Once again it is a case of "whose ox is gored." The great admitted virtues of American cars are durability and performance, the less admitted virtues are appearance, comfort and low cost per pound. In fact, many Europeans are in the stage where gear shifting is one of the positive satisfactions of car ownership! Before leaving the reader to make up his own mind about these apparent dilemmas, we may note that perhaps gear shifting is desired because it seems as though man is thus in control of the machine and materialism is being kept at bay as useful but degrading.

Productivity and Increased Wages

by **ROBERT B. SEIDEL**

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MANUFACTURERS and economists are generally in agreement that increasing wages must be supported or preceded by a corresponding increase in productivity. Although we accept this point as fundamental, many manufacturers approach the bargaining table or the budget planning committees with no specific technique of tying this economic fact of life into these programs. Exactly how do we calculate, with a given productivity increase, the maximum amount available for a general wage increase? What is the effect of increasing material cost, expenses, and interest on money?

In an attempt to develop a method for more rigorously planning budgets, and in particular, the amount of wage increase that can be tolerated for direct and indirect people over the course of the year and still fulfill over-all company objectives, the equations start from the basic pie chart of distribution of the company sales dollar. Although analysis yielding similar results could be made by working with the total dollar figures, they become cumbersome and do not reflect the underlying causes which produce the total dollar figures involved.

DEVELOPMENT OF EQUATIONS

For this reason, the original pie chart of the sales dollar has been set down as an equation and expanded into a more intricate form which reflects the underlying causal factors. Management must work with causal factors to produce end results. Starting this original pie chart we can write:

$$S = W + M + E + F + P \qquad \text{Eq. 1.}$$

Where the symbols in Eq. 1. are:

- S = The total net sales
- W = Total wages paid (both direct and indirect and associated fringes)
- M = Total cost of materials and supplies
- E = Total directly variable expenses such as power, commissions, direct incentive payments, etc.
- F = Total fixed expenses such as depreciation, heat, rent, etc.
- P = Total operating profits

If the total number of employees equals N, we can eliminate the employee variable by dividing both sides of Eq. 1. by N, yielding:

$$s = w + m + e + f + p \qquad \text{Eq. 2.}$$

Where $s = S/N$

$w = W/N$

etc.

If, in the year just completed the subscript 1 is used in Eq. 2. to denote the per employee variables indicated and subscript 2 is used in the same equation to denote the future year which is being budgeted, we can write equations relating similar variables in Year 1 to those variables in Year 2 as follows:

$$s_2 = Gs_1$$
$$w_2 = Rw_1$$
$$m_2 = Gckm_1$$
$$e_2 = Le_1$$
$$f_2 = Kf_1$$
$$p_2 = Tp_1$$

Where:

- G = The ratio of per employee shipments in the Year 2 to per employee shipments in the Year 1 or the productivity per employee factor.
- R = The factor by which wages can be increased or decreased. Ratio of wages per employee in Year 2 with respect to Year 1.
- c = Ratio of the change in cost of materials due to price increases, better buying methods, etc. in Year 2 with respect to Year 1.
- k = Factor reflecting the change in purchasing habits. For example, creation of a new department to manufacture parts that were formerly purchased on the outside. (In Year 2 with respect to Year 1)
- L = Ratio of direct variable expenses per employee in Year 2 with respect to Year 1.
- K = Ratio of fixed costs per employee in the Year 2 with respect to the Year 1.
- T = Ratio of profits per employee in the Year 2 with respect to the Year 1.

It is to be noted that G, R, L, K, and T are on a per employee basis and if developed by historical data and projections on the basis of total dollars, they must be divided by the number of employees in the Year 1 and 2 respectively to reduce them to the above form.

PROJECTED EQUATIONS

Substituting the above equations in Eq. 2. we can write an equation for the projected "pie chart" for the Year 2 as follows:

$$Gs_1 = Rw_1 + Gckm_1 + Le_1 + Kf_1 + Tp_1 \qquad \text{Eq. 3.}$$

Dividing both sides of the equation by s_1 and substitut-

ing its equivalent value by Eq. 2. we obtain:

$$G = \frac{Rw_1 + Gckm_1 + Le_1 + Kf_1 + Tp_1}{w_1 + m_1 + e_1 + f_1 + p_1}$$

Rearranging and solving for R the factor by which wages can be increased, we obtain:

$$Gw_1 + Gm_1 + Ge_1 + Gf_1 + Gp_1 = Rw_1 + Gckm_1 + Le_1 + Kf_1 + Tp_1$$

$$Rw_1 = Gw_1 + G(1 - ck)m_1 + (G - L)e_1 + (G - K)f_1 - (T - G)p_1$$

$$R = G + G(1 - ck)\frac{m_1}{w_1} + (G - L)\frac{e_1}{w_1} + (G - K)\frac{f_1}{w_1} - (T - G)\frac{p_1}{w_1} \qquad \text{Eq. 4.}$$

PLANNING THE BUDGET

The foregoing equation has been solved to yield the factor R by which wages may be increased in the following year in order to allow us to fulfill all other requirements of the budget. This is the form in which the equation is most frequently desired to do a mathematical job in planning the budget. The method of proceeding from this point to establish yearly budgets differs from the old method as will be shown in the following example. In the older method, sales forecasts are established for the coming year and department heads are asked, on the basis of this sales forecast, to submit a dollar budget for their departments to accomplish this goal. The tendency is, without being given other instructions or guideposts, to submit an ample if not padded budget, since the department head expects to be cut down by management to a figure which will meet the profit objective. This cat and mouse game, although possibly yielding a workable program for the year may not be a balanced program between departments, since the more conservative department head frequently suffers in the same proportion of cutback as the department head who has admittedly submitted an overstuffed budget.

In the method of a mathematically planned budget, the sales forecast is made just as before and then each department head is asked to forecast the minimum number of employees that will be required (average throughout the year) to accomplish the forecasted sales program. It is to be noted that this is a much more accurate and easily forecast figure than a total dollar budget. Most department heads can do a very excellent job of estimating the number of people required to accomplish the program after that program has been outlined. From these two figures only, the Accounting Department takes over to develop the constants needed for Eq. 4., and to ultimately come up with the factor R by which each department head can increase his per employee payroll as a maximum. This factor then sets the objectives for the Union negotiations, for the weekly and monthly wage classification adjustments.

EXAMPLE

As an example of this procedure, the following hypothetical factors from the Year 1, just completed, are itemized from our financial and personnel records.

S_1 = \$10,000,000.

N_1 = 1,000.

s_1 = 10,000. dollars/employee

w_1 = 4,350. dollars/employee

m_1 = 2,850. dollars/employee

e_1 = 1,000. dollars/employee

f_1 = 800. dollars/employee

p_1 = 1,000. dollars/employee = 10% operating profit

From the forecasted sales figure of \$11,000,000.00 and the sum of department heads' employee requirements for the new year, 1,048 employees, the following factors are projected.

S_2 = \$11,000,000.

N_2 = 1,048 employees

s_2 = 10,500. dollars/employee

$G = \frac{s_2}{s_1} = 1.05$

$c = 1.02$

$k = 1.00$

$L = \frac{e_2}{e_1} = 1.02$

$K = 1.0$

$T = 1.1$ (10.5% operating profit)

$R = ?$

s_2 is of course the ratio of S_2 to N_2

G, or the productivity factor comes directly from the ratio of s_2 to s_1.

c—can be developed quite accurately from records maintained by the Purchasing Department on the cost of materials purchased in the present year as compared with the last purchase price of the same material in the last completed year. If these figures are compiled irrespective of quantity change, design change or price change, it produces an historical record which quite accurately re-

flects all of the variables on a per unit cost of material as a function of total sales. This historical record along with a forecast of national price index, will yield surprisingly accurate figures for c.

k—this factor reflects major changes in purchasing habits such as the establishment of a new department to manufacture what was previously purchased and will frequently be one as in the above example if no major changes in purchasing habits have occurred.

L—historical records of the data relating directly variable expenses per employee to total sales will yield quite accurate figures for L, if projected to the new sales volume.

K—most frequently will remain at one, as in the above example unless major changes in assets such as new buildings, divisions, etc., enter into the picture (at a rate which exceeds the rate of change in number of employees). If such changes occur, the figure K can be accurately and rigorously forecast by the Accounting Department from the knowledge of the total projected assets for the Year 2 as compared with the assets in the Year 1 just completed.

T—is the arbitrarily determined constant on the part of management to decide what profits must be achieved in the new year. In the foregoing example, an increase of 10% in the per employee profits is demanded by management which yields a 5% increase in per cent operating profits to net sales.

The factor R, by which wages can be increased for the average employee throughout the entire organization remains to be determined.

Substituting the above figures in Eq. 4., we get:

$$R = 1.05 + 1.05(1 - 1.02)\frac{2850}{4350} + (1.05 - 1.02)\frac{1000}{4350} + (1.05 - 1)\frac{800}{4350} - (1.1 - 1.05)\frac{1000}{4350}$$

$$R = 1.05 - 1.05(.02)\frac{2850}{4350} + (.03)\frac{1000}{4350} + (.05)\frac{800}{4300} - (.05)\frac{1000}{4350}$$

$$R = 1.041$$

Having determined that a 4.1% average increase in per employee wages can be tolerated in the coming year, management returns this figure to the department heads along with the other constants which apply to their direct expenses, etc. The department heads then proceed, given the sales objective, the number of employees in their department and the ceiling ratios for wages, expenses, etc., to develop the detailed dollar budgets which are in turn resubmitted for approval to management.

The establishment of the wage factor R sets a very firm objective for the Personnel Department in negotiating the Union Contract for the new year and if successfully accomplished yields a far more accurate and scientifically planned program for the new year.

SUMMARY

The foregoing mathematical approach and equations can be extremely valuable in making alterations in the program which are necessitated by changing factors in the course of the year. For example, if Union negotiations resulted in increases in excess of the allowable as determined by the factor R, new objectives could rapidly be established for the Purchasing Department, the number of employees per department, the capital expansion program, and as a last resort the desired profit for the year.

For example, if we were to assume that the wage negotiation finally ended up at a 5% increase instead of a 4% increase, a very rapid management appraisal of the value of purchasing additional automation equipment could be made by increasing slightly the factor K to account for the depreciation of this additional capital equipment and correspondingly reducing the factor N_2 for the number of employees that will result from such automation to determine the adjusted effect on operating profits. It is to be noted that the factor $(G-K)f_1/w_1$ which is the expression showing the effect of increase capital assets, has a strong effect on profits. If automation machinery is purchased, increasing the value of K, it will also increase the value of G, which is the productivity per man. As an example, let us assume that in the wage negotiation, we were unsuccessful in holding to the 4% increase indicated by the original example and in fact had to pass on a 5% increase in wages, management then studies the question as to whether or not original profit or objectives can be recuperated by the purchase and application of automation machinery. For this example, assume that management is considering the purchase of $100,000.00 additional automation machinery beyond the original capital assets program. If this cost were added to the fixed cost of the original example, it would increase it by about $12,000.00/year (allowing for depreciation and interest on borrowed money). Let us assume further that this $100,000.00 of additional automation equipment would enable us to produce the $11,000,000.00 sales objective with 1,020 employees rather than 1,048 as in the original budget, substituting these revised factors which results in a productivity per man factor of 1.08 and a change in fixed cost constant of $K = 1.01$, we can substitute these new values in Eq. 3. and find that the profits under such a program would come out 11.4% of the net sales dollar, which more than offsets the additional wage increase passed on. It can, therefore, be seen that an increase in capital assets of an automation nature will usually improve productivity at a greater rate than it increases the fixed cost and thereby greatly improve the profit picture. In this case, management would then make the decision to install immediately this additional equipment and send out new manpower per department objectives which must be maintained in the revised budget.

Work Sampling by Fixed Interval Study

by **I. LANDIS HAINES***

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FOR OVER ten years, we, here at Lukens, have used a work measurement technique that we have commonly called a "two-minute study." As we have also used this procedure at either one or three-minute spacings, it might be better to term it generally "fixed interval work sampling."

When first I began to read about ratio-delay study, which has become better known recently as work sampling, I was not particularly impressed with its newness —feeling that we had been using it all along. However, when I began to study the procedure more thoroughly in the excellent books of Ralph Barnes (1) and the still later volume by Heiland and Richardson (2), I began to realize there was a basic difference of concept in the procedure we were using. All the writings on the subject stress the importance of the randomness of observation, whereas we, by deliberate intent, had established a regular or fixed interval of the observation. Also in our case, no confidence intervals were computed, but rather were assumed. Consequently, I was compelled to ask myself a very searching question: "Have we been using a procedure that was inherently inaccurate?"

This presentation, therefore, will be an attempt to validate our technique for that type of problem to which it is applicable.

WHY IT WAS STARTED

Some years ago we were confronted with a problem of making a multi-man study with a single observer. If there is some variation in the duties performed by the various members of such a group (as there usually is), taking a study of this kind is extremely difficult. For example, in studying a five-man group, the time study observer would be obliged to account for a total of 2400 man minutes during an 8 hour study. Using the snap-back method of time study, readings had to be taken each time any member of the group changed his type of activity or, for any reason, ceased to work. It was then necessary, of course, to record that reading against all the five operators being studied. Because of inherent difficulty that is involved in such a procedure, I was never particularly impressed with the accuracy of the results, even when all the elapsed minutes might actually have been accounted for.

This, then, was the problem confronting us: A group of operators performing different, although related tasks, in an area where the whole group could, when working, be in view of one centrally-located observer. Our solution was to consider the 8 hour turn as being made up of a large number (either 160, 240 or 480) of small equally spaced units of time. The activity of the various members of the group under observation was recorded as nearly simultaneously as possible on the pre-determined fixed interval. The basic assumption was that these activities were random by nature, of varying lengths or duration and generally longer than the interval of observation. In statistical parlance, the procedure which we had developed intuitively to meet a specific need is fixed interval sampling of activities that in themselves occur randomly over an 8 hour span. As such, simple random sampling formulas could be employed.

TYPE PROBLEMS TO WHICH APPLICABLE

This procedure, in common with most work sampling techniques, has a somewhat limited field of application. In our own company, for example, it definitely has not replaced stop-watch time study. However, in such fields of activity that follow, it has definitely proved of value to us:

1. Determination of idle or delay time for a large group of workers.
2. Used in conjunction with pace rating to develop the work load for a crew or gang of men.
3. To record the state of activity of a battery of machines or furnaces that operate independently of each other.
4. As a means for developing appropriate factors for miscellaneous work after basic work standards have been established through conventional time study.
5. As a quick method for auditing the over-all accuracy of a group work measurement plan.

No doubt, there are other areas to which this technique could be applied. However, it should be considered as a limited purpose tool and not, by any stretch of the imagination, as a cure-all.

THE RELIABILITY OF THE TECHNIQUE

As was indicated in the preceding section, we have used this procedure, both with and without leveling or pace rating the work being performed by the group under

* The author wishes to express his appreciation to Messrs. Paul E. Green and S. Reed Calhoun, also of Lukens, for their guidance in the use of the statistical proofs shown.

observation. It is our personal belief that this leveling is neither more nor less accurate than the leveling used in conventional time study. Therefore, rather than introduce this additional area of possible controversy, and to keep this problem statistically "clean," we would attempt to indicate the accuracy of this technique based on its measurement of time alone. Accordingly, we will demonstrate the accuracy of the proposed method by two different and distinct tests.

1. Taking a group of old, continuous-reading studies, we will lay them out in exact intervals as would occur under this method, and then determine how close results check with the time obtained by the continuous-reading method.
2. In a check study set up expressly for this purpose, we will compare the time obtained by one observer covering 3 individuals simultaneously by this method against the separate times obtained by 3 other observers checking each of the 3 men individually.

If these two tests prove to both our and your satisfaction the practicability and reliability of this technique, we feel that this presentation will have served its purpose.

1. CHECK OF PROCEDURE AGAINST OLD, CONTINUOUS TIME STUDIES

To make this comparison applicable to the type of problem for which it is intended, we selected an operation of a servicing nature—one in which the work requirements were both varied and restricted by the demand for service. Therefore, we dug out a batch of old time studies, taken on what we know as a "process study" form, that were actually used in developing several of our present standards.

The four studies used in this analysis are of approximately 7.5 hours' duration each. In order to simulate the two-minute intervals of the proposed sampling procedure, the actual times recorded on these studies were laid out on graph paper with each 0.1″ block representing one minute. Working time was designated by one color and idle time by another. Readings were taken at regular two-block intervals and the status of the operation determined accordingly. The 95% confidence level was used to evaluate the differences between the results of the original studies (which were assumed to yield "true" measures, p′) and the two-minute interval sampling results (p). This was done in the following manner:

Original Studies

Study No.	*Tot. Min.*	*Idle*	*Working*	(p') *% Work*
1	432.03	149.63	282.40	65.3
2	434.34	216.73	217.61	50.1
3	455.42	236.69	218.73	48.0
4	443.52	245.26	198.26	44.7
Totals	1765.31	848.31	917.00	51.9

where

$$p' - 2\sigma < p < p' + 2\sigma$$

$$\sigma = \sqrt{\frac{p'(1.00 - p')}{N}}$$

p' = the "true" average

p = sample average

N = number of observations

for

$p' = 51.9\%$ or .519; $p = 51.4\%$ or .514; $N = 884$

$51.9 - 3.3 < p < 51.9 + 3.3$

The 95% confidence limits are 48.6% and 55.2%.

The results obtained from this comparison are as follows:

Two-Minute Intervals

Total	*Idle*	*Working*	(p) *% Work*	95% *Confidence Limits (%)*	
432	156	276	63.8	62.1	68.5
436	212	224	51.3	46.7	53.5
456	242	214	46.9	44.6	51.4
444	248	196	44.1	41.6	47.8
1768	858	910	51.4	48.6	55.2

The above comparison indicates that the percentages obtained by fixed interval work sampling are not significantly different from those obtained through regular time study on this type of operation.

2. COMPARISON OF TIME STUDY WITH "FIXED INTERVAL WORK SAMPLING"

An actual 8 hour study was made of a handling and servicing group in one of our operating departments. Continuous time studies were taken on the layerout and the two floaters by individual observers studying each man separately. Another observer, using the two minute interval technique, covered the above three groundmen independently of the men observing them individually.

Actually this man also included in his study the two cranemen working in the department. Since this latter was beyond the scope of this comparison, no figures for these two operators are presented. It is mentioned merely to detail the conditions under which the study was taken and to indicate the larger number of operators to which this technique may be applied.

For those of you who (like ourselves) accept the concept of rating or leveling, we are including the standard minutes and the related work indexes. If you think the work indexes shown are abnormally low, you are right. The work performance of this handling and servicing operation ordinarily averages about 50%; we just happened to hit a low day for our study. This condition also contributed to the bias introduced by the operators being studied; they were naturally trying to appear busy by extending their working time.

Here are the results obtained from this comparison.

	Layerout	*#1 Floater*	*#2 Floater*	*Comb. Totals*	*Totals from Work Sampling*
Total Minutes Studied	479.99	478.99	481.70	1440.68	1440
Total Idle Minutes	280.53	327.72	300.41	908.66	890
Total Working Minutes	199.46	151.27	181.29	532.02	550
% Working Time	41.6	31.6	37.6	36.9	38.2
Total Standard Minutes	227	133	158	518	532
Work Index (%)	47.2	27.8	32.9	36.0	36.9

As can be noted from the above data, the percent working time obtained from fixed interval work sampling was 1.3 points higher than the actual observed figure. Converted into a percent of the actual average working time, this still only shows a 3.5% deviation, well within the accuracy limits of our standard rating procedure.

Assuming that the variations obtained from our sampling technique will approximate a normal distribution, the results may be validated by the same formula previously used.

Using the allowable 95% confidence interval we have a range from 33.3% to 40.5%. The actual 38.2% obtained from work sampling, not only falls within this range, but is less than one standard deviation from the "true" value.

Well, up until this point, we weren't quite sure. Although our procedure was practical from an Industrial Engineering standpoint, in that it obtained results quickly, we had accepted it pretty much on faith alone. Now, we know that it is also a valid procedure statistically if the activity being observed follows a random pattern.

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President's Message

GORDON B. CARSON
President, American Institute of Industrial Engineers, Inc.
1957-58

*Progress**

PROGRESS has been defined by some writers as the development of a "higher stage." Others simply call it a steady movement forward. Whatever the definition may be, one thing is clear: it is uphill. No real human progress has ever been made without drive, determination and courage on the part of those who will fill the role of leaders.

With progress there is always present a certain group who are disturbed by what is being done. To them, any change is disturbing and frustrating. They would prefer the tranquility of known pursuits and tested methods. Inevitably progress is accompanied by another group whose motto seems to be "let's change everything." Both groups are wrong.

To the profession which is able to use its sages wisely, and its energetic new comers with direction and purpose, progress is no stranger. But to the profession where these invaluable groups are unrecognized or unused, progress comes haltingly, if at all.

Recently some comment was heard about those who doubt the efficacy of certain new techniques in Industrial Engineering. Such doubt is not to be deplored if it is sincere. Browning put it this way:

> Rather I prize the doubt,
> Low kinds exist without
> Finished and finite clods
> Untroubled by a spark.

There is a vast difference between intelligent doubt and subjective obstructionism. One builds a profession, the other can destroy it.

Industrial Engineering is on the threshold of a new era. We in AIIE are now constituent members of the Engineers Joint Council. We are now recognized as the spokesman for professional Industrial Engineering in the United States. But like an airplane in flight, we cannot continue progress unless we keep the power on. And our flight will be meaningless if we do not heed our instruments and consult our flight plan.

There is much we need to do—not once, but on the basis of continuing progress. Among these important projects are:

1. The development of a new dictionary of Industrial Engineering terms, revised repeatedly at sensible intervals to keep it up to date.
2. The continuation of AIIE stimulated high level "short course" programs to assist professional Industrial Engineers in their personal professional progress.
3. The continuation of vigorous effort to stimulate further research fundamental to Industrial Engineering theories and practice.
4. The continuation of the development of new chapters in areas where Industrial Engineers reside in sufficient numbers.
5. The provision of further publication services to members.

I am grateful to you, our fellow members, for your generous support during my year in office. Especially, am I grateful to the other officers, the board members, the directors, the committee chairmen, the publications editors and th chapter officers, whose energy, foresight and skill have moved us up the ladder of progress this year.

Keep on keeping on!

Ed. note: This message was inadvertently omitted from the May-June issue.

Intellect, Skill, and Tools

IT HAS become fashionable for educational sophisticates to look askance at "tool skills," and to infer that any educational activity which touches upon such skill is, indeed, of very inferior quality.

At the same time, the artisan has long looked with contempt upon the long haired impractical theoretician who can "talk long but accomplish little."

Since both groups represent extreme fringes in Industrial Engineering it would behoove us to examine carefully the area between them, and evaluate the task which we as Professional Industrial Engineers have facing us.

Intellect is the only characteristic which can improve with each passing year in a man's life. But such improvement is not automatic. Any human characteristic left alone in time deteriorates. Investigation, effort, and constant reappraisal are the only roads to improvement of the intellect. Some observers counter with the thought that intellect is strictly "in-born," and cannot be markedly altered. The intellect we speak about, however, is not narrow, nor is it measured by the number of gray cells possessed through heredity. It is the end result of the possession of such cells by an individual who *uses* them to solve problems, and to make clear the abstractions upon which his field of applied science must be based. In this connotation intellect is the sum total of the accomplishment of a man through the application of his mental powers to solving problems.

Intellect alone is not enough. It must be accompanied by *skill*. The English language often proves inadequate because some of its words have many different meanings to those who use it. Skill to a craftsman means manual dexterity coupled with job "know how." Skill in sports implies the ability to outwit the opponent with the least physical attrition upon one's self. And it also implies being a little faster, or a little more accurate, or possessing a little more stamina than the opponent.

Skill in teaching implies *effectiveness* in stimulating and inspiring the student. Skill in speaking implies contagious enthusiasm, clear exposition, and engaging presentation.

Whatever the zone of application, skill is a most important ingredient in building the stature of a man. We must not lose it in our educational process. Graduates of any professional program must not only be intellectually capable, they must be skillful enough to put this intelligence to work in a highly competitive world.

No sane individual would go to a concert in which musicians of great theoretical knowledge were to perform without skill. No one would willingly submit to the ministrations of a surgeon whose knowledge of anatomy was profound, but whose surgical skill was undeveloped. These facts are lost in some of today's approaches to the education of the engineer. Fundamentals in mathematics, the physical sciences and in psychology are the necessary composite platform upon which Industrial Engineering education must rest. Much greater intellectual capacity in dealing with complex concepts must be developed. Courses devoted primarily to the perpetuation of historical techniques must be superseded.

The Industrial Engineer must specify; he must design; he must *conclude*, and *apply* his knowledge. He cannot forever devote himself to redefining the problem . . . he must *solve* it, and then attack the next one. This kind of intellectual skill can be developed in a case study laboratory which looks ahead. It cannot be achieved in a program of work books and answer sheets.

Tools are one of the important differences between man and other creatures. While we must unquestionably avoid manipulative skill attitudes toward tools in higher education, it might be well to re-examine the importance of tools, first to man, and secondly to the Industrial Engineer.

Through the ages, the development of civilization has been directly related to man's tools. Familiar to all of us are the great "ages": the stone age, the bronze age, and the iron age—and more recently the industrial revolution—the age of mechanization—and now the age of automation and nuclear power. All of these ages of man refer to his tools and to his method of using them.

To teach the skill of an artisan in a university may be unwise; to ignore completely the "tools" with which we must work is worse.

The Industrial Engineer of tomorrow must know how to gather, sort, codify, validate and use *information*. Before he can do this, he must know what information is. To fail to explore the methods by which he may perform such services rapidly would be dereliction of the highest order in education. Computers, both digital and analog, are tools. Their design and programming requires both the intellectual capacity to interpret "information" and skill to apply it to the tools (computers) which will then proceed according to the instructions given to them.

Time study, motion study, and the utilization of process charts are simply information gathering techniques. They are not ends in themselves.

Diagnosis is extremely important. But without adequate treatment of the patient, it would be purely an academic exercise in medicine. Similarly, it is not enough for the Industrial Engineer to know what the treatment ought to be—he must know how to sell and implement the program. If he doesn't, all his efforts have been meaningless.

Industrial Engineering is *Applied Science*. The cumulative effectiveness of its activities depends upon the results therefrom. A single minded devotion to theory in Industrial Engineering education will not provide the background needed by men who must analyze, solve, sell the solution, and then see that the plan of action is faithfully executed.

President's Message

GEORGE H. GUSTAT

President, American Institute of Industrial Engineers, Inc.

1958-59

The Challenge of Maturing

Acceptance Speech as President of the American Institute of Industrial Engineers*

IT IS quite an honor to be elected the President of the American Institute of Industrial Engineers for the year 1958-1959. It will probably be difficult to follow a man of Dean Carson's caliber, and the fine record that he has established this past year. I can only promise you to discharge the duties of this important office to the best of my ability.

Now, I would like to talk about the service that the American Institute of Industrial Engineers offers to men in this field and their desire for professional identity.

The history of Industrial Engineering is not much different than that of other fields of engineering. All of nature seems to be organized in such a manner that a newcomer to any group is first regarded with suspicion, then with derision, then with jealously before being finally accepted.

Relatively a short time ago doctors were regarded as sorcerers and quacks, and the village barber was the physician whose cure for everything was blood letting. Within our short memories, yes even in some of today's literature, train operators and janitors are sometimes called engineers. The older fields of engineering have always objected, and perhaps someday the term engineer will mature to the uniform and dignified professional status now accorded doctor in the field of medicine.

Industrial Engineering is among the newest of the engineering fields, and since the whole world is moving faster than ever before, the Industrial Engineering profession is going through these four stages a little faster, than the others.

Just a very few years ago such terms as industrial economy, efficiency experts, time study, rate setters, and perhaps other less complimentary terms were used to describe the Industrial Engineering functions. Today there are still those who use these terms, but for the most part the term "Industrial Engineer" is understood and used to describe our area of work and responsibility. We have gone through a stage where a great many other engineers looked at our field and asked, "Is it really engineering?"

* Presented: Hotel Statler, Los Angeles, California, Saturday, June 14, 1958.

Indeed, many schools added a few courses to their business curricula and claimed to be processing Industrial Engineers. The other engineering schools looked at the Industrial Engineering curricula wherever it happened to be, as a place a student could graduate from when he flunked some other branch of engineering.

If one felt the need for professional recognition, his only outlet was through organizations such as S.A.M., the Taylor Society, etc. Through this stage of development it was a little difficult to get a very firm sense of professional feeling.

So far this is a rather dismal picture of our profession —but no more so than any other profession has experienced in its infancy. Now let's look at the credit side of the ledger.

One of the chief things that has enabled this country to win two world wars has been its ability to produce enough matériel for both ourselves and all of our allies. This same ability has given us the highest material living standard in the world. I'm sure you all have seen the statistics on the number of phones, TV sets, automobiles and individually owned homes. High productivity, of course, is the result of the work of everyone in industry. Management, labor, all fields of engineering and science make important contributions, but it is the Industrial Engineer's chief job.

This is recognized by many, others than ourselves. By far the great majority of foreign technicians that come to this country through our State Department are seeking knowledge of our productive know-how. They are intensely interested in Industrial Engineering and spend most of their time with us in both universities and industry to learn our way of thinking. Industrial Engineering has made an extremely large contribution to our productivity, and it is recognized by the entire world. This development has been a dynamic one and has meant that the Industrial Engineering work done has had to keep pace with the whole field of improving technology.

The educational institutions have recognized this, and in the past decade a great many have improved and strengthened the Industrial Engineering curricula. More and more of them are setting it up as an independent program. Men with this kind of training get going quicker, accomplish more, and have won the respect of the other fields of engineering. The change in Industrial Engineering in the past ten years offers so much challenge that it has attracted many others into the field. Automation groups, operation researchers and almost all other captive engineers in any plant are either doing or trying to do some of the Industrial Engineering functions. Hence, we have reached a stage of real acceptance, when others try to take over our functions; you seldom hear the phrase anymore, "Is it really engineering?"

With this growth, which attracts and holds higher types of engineers, a definite need for professional recognition grew. Accordingly, ten years ago the American Institute of Industrial Engineers came into existence. By now there are over 80 chapters and over 8,000 members of different classes. We recently have been accepted to full membership in the Engineers Joint Council, and have quite a few members that are active in their projects. Plans for this next year provide for regular publicity in the Journal on how the Engineers Joint Council serves all of the engineering fields, and the part that the Institute plays in the Engineers Joint Council. Our excellent *Journal* offers you opportunity for written expression on a high technological plane.

I have had many opportunities to speak before our chapters and other societies. The attendance and enthusiasm at the American Institute of Industrial Engineering meetings is the envy of all other societies.

All of these things are the manifestations of the virility of youth. We are a young organization and moving fast, because of the type of members involved, the economic situation that requires a better job of Industrial Engineering and developments in the technology of our profession.

As we mature there may be a tendency for this momentum to slow a little; pressures will develop to lower our standards for acceptance into the organization, and as our jobs increase in scope there will be more encroachment by other groups with different and perhaps even more exotic names than those mentioned. In short, we must not be misled that our future is going to be free of problems.

What this means is that the strength of maturity, and the sounder judgment of age, must compensate for the eagerness of youth.

Not only will we have to fight to keep those functions which the Industrial Engineer has traditionally performed, but we should also back off and take a look at those functions that could more profitably be performed by the Industrial Engineer than anyone else. One such area, and it is an extremely difficult one to solve, is to work ahead of, and with the designers.

The Industrial Engineer, of course, has always had the job of trying to balance labor and equipment after it is built, and to fit both into the productive system. With the increasing complexities of productive machines and soaring costs for such equipment it becomes increasingly more important that the use of these heavy investments be maximized. In this sense we differ from the other fields of engineering in that we bring knowledge of the physical sciences to the behavioral sciences. No matter how involved in automation we may become, it will still require human skills to operate our systems. This type of work can have a high factor of boredom and a serious loss of a sense of accomplishment on the part of the people involved. This creates new work for the Industrial Engineer. Contents of jobs must be studied, perhaps by job enlargement analyses to restore pride of work. In short, this will require closer and closer cooperation between the

Industrial Engineer, the designer, the medical people and the psychologists.

The ideal approach, of course, is for the Industrial Engineer to study the requirements for a long time ahead and design a system with synthetic cycle times that will economically justify the investment necessary, and which will still offer the people operating the system some challenge and a measure of job satisfaction. If the designers could work from this kind of information, you can depend on it that controls will be better placed, effort to operate the equipment will be minimized, maintenance will be minimized, and the designer will have a much better idea of how far he should go in mechanizing the system.

Designers resist this kind of help, because they regard this as part of their job. Unfortunately they are not trained in making these kinds of analyses.

It is also very normal to want to mechanize everything. There seems to be sheer fascination in a complex machine, and even though fun gets poked at the concept via the "Rube Goldberg" cartoons, it is a very real problem.

The Industrial Engineer should be concerned in his pre-analysis not only with design of a project as a whole, but also with the evaluation of the component parts. Often it is more effective to do some things manually even though most of the operation is mechanized. All too often the flexibility necessary to meet varying requirements is lost upon mechanization unless such studies are made. Here, indeed, is a lucrative field of work for the Industrial Engineer.

If team work of this kind is to take place between the Industrial Engineer, the designer and production personnel, and perhaps even the psychologist, all must appreciate the value of such an approach.

True, the mechanical design departments will resist this. Perhaps the place to start to sell the idea is back in the college curricula. Perhaps through the cooperation of the American Institute of Industrial Engineers and the Engineers' Council for Professional Development, we can influence changes that will make future design engineers and others welcome this help.

This problem is not limited to Industrial Engineers alone; Chemical Engineers, Electrical Engineers, Mechanical Engineers, and Civil Engineers are not too prone to accept help from each other. True, each gets a few courses in the other fields of engineering, but the courses are aimed at giving specific know-how. There just simply isn't time for a man to get completely trained in all fields, and taking one to two courses may be the case of "a little knowledge can be dangerous." With this inadequate knowledge a good many men when they get into practice fail to realize that parts of their job can more effectively be done by others. Therefore, if the emphasis in cross training courses could concentrate on the help that other fields can give, and the overall importance of a cooperative effort, perhaps the entire engineering field could become considerably closer knit. Cooperation of this kind between engineers will go far to unify the entire profession and to command respect by the entire world for the term, engineer.

For those of us already on the firing line, we will have to do our own educational job and demonstrate through accomplishments that it will work. We will have to continue to master the new Industrial Engineering tools that come along, for instance: The use of engineering mathematics opens up fields that will immensely increase the value of the service that can be given by the modern Industrial Engineer.

If you have not used these sharp tools, or perhaps I should characterize them as a sharper way of thinking, I am certain you will find that using them is a tremendously stimulating and productive experience.

To list a few of them:

Basic Probability
Statistical Sampling
Significance Testing
Regression Analysis
Simulation—Monte Carlo
Multivariate Analysis
Matrix Algebra
Mathematical Programming
Queueing Theory
Boolean Algebra

Familiarity with and ability to apply mathematical reasoning allows us to tackle problems that were beyond our abilities just a few years ago. We can get data quicker, and more accurately than ever before. The advent of fast computation has given a real impetus to the use of these techniques and has brought the biggest of management problems down to where the vast amounts of data necessary are economically possible to collect. Furthermore, this information can be gotten quickly enough to really be useful.

Fortunately this kind of thinking applies to small problems as well as large ones and best of all, it does save a lot of engineering time.

The universities have added training of this type in the curricula, and it is possible through many other mediums to acquire this type of knowledge.

I have several words of caution in this regard: there is no magic in this approach—it is only a useful set of knowledge to have; do not discard your old Industrial Engineering know-how—but by all means find out more about the newer developments.

As Industrial Engineers we must always continue to educate our managements to the ever broadening scope of service that we can perform for them.

The American Institute of Industrial Engineers provides an excellent tool to help achieve this. Your participation in, and contributions to, the Institute cannot help but impress these management people.

The *Journal* with its high level of technological information on management functions can be used to good ad-

vantage. These and many other uses can be made of your Institute to enhance your professional status and prestige in the eyes of your own management. This kind of use of the Institute is bound to keep it improving and will insure that our progress in the future will be even greater than in the past.

Wisdom and progress are born out of experience, and most of all out of precisely such experience as is brought by our darkest moments. It is in meeting of such moments that are born new insights, new powers and new skills.

We are not going to achieve our high goals by any single stroke, or by any one strategy sprung from the mind of any single genius. Rather, we must pin our faith upon the inventiveness, the resourcefulness, the initiative of every one of us. We must keep faith in ourselves and our future, and in the constant growth of our intelligence and ability to cooperate with one another.

Our chief concern, of course, is the continued growth of the prestige of Industrial Engineering, but again as you take a broad look, you must realize that the entire engineering profession must move ahead together. By the very nature of our work, we can do a great deal to spark this movement. Through the Institute and its close relations with the Engineers Joint Council and the Engineers' Council for Professional Development and the National Society of Professional Engineers, we have the opportunity to speak with the power of approximately 8,000 voices. In addition, each of us must live this philosophy on the job, and if we do there can be little doubt but that our objectives will be attained.

CONFERENCE EXHIBITS*

STATE OF WASHINGTON DEPARTMENT OF COMMERCE AND ECONOMIC DEVELOPMENT

Olympia, Washington

This Department is a newly formed addition to the State of Washington governmental activities.

The basic objective of the Department of Commerce and Economic Development is to create a true Department of Commerce for the State of Washington, which will serve as representative, spokesman, protector, and, at all times, servant of the business and industrial community of the State, in terms of those matters of program, policy, and action at State levels of government conducive to a good business climate.

By a good business climate, is meant those conditions of economic fact and political attitude that permits existing business to grow and prosper and that serve as an attraction to bring new business and industry into the State.

The purpose of the Display Booth was to acquaint those present at the convention with the State attitude towards business, and to show the physical attributes of this State which will have, in the next twelve years, a 34% increase in the population of the trade area served.

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UNIVERSITY OF CALIFORNIA

Los Angeles 24, California

The U.C.L.A. Exhibit will include an artistic display of brochures and announcements covering most of the facets of Industrial Engineering instruction as well as conferences and seminars. Materials concerning the production management courses, the Engineering Executive Program, the Statistical Methods in Industry course, and Cargo Handling will be shown. Research publications concerning industrial engineering will also be displayed.

* These summaries were received too late for publication in the May-June issue.

Reader Comments

ON CALCULATING THE RATE OF RETURN ON AN INVESTMENT, by R. O. Swalm, *Journal of Industrial Engineering,* March-April, 1958.

Again our profession should be grateful to Professor Swalm for drawing attention to an important problem in "Engineering Economy." His choice of "Allegoric Ole" not only allows him to keep his own tongue firmly in his cheek, but permits his readers to respond in an equally light-hearted manner without hurting anyone's feelings. We should have had "Ole" in discussing machine replacement formulas in the Jan.-Feb. and Nov.-Dec. issues of 1955.

In my eleven years of teaching (I am now retired) I encountered many "Oles"—even among graduate students. All were good mathematicians and curve drawers, although many could not explain *why* they used semi-log and log-log papers when obviously their curves were still curved. But their greatest fault was not in the manipulation of data—it was in their superficial understanding of the basic factors and relationships. Like the proverbial "handbook engineer" they appropriated formulas from many sources and chuckled over the inconsistency thereof without searching for the *assumptions* which produced the discordant results. This, of course, was great fun but not engineering.

My advice to "Ole" is to examine Professor Swalm's four equations a little more carefully, correct any misunderstandings, and recompute the simple problem which he has set up. If he does this I am sure that the variation of results will be far less than the 15.3%, 10%, 20% and 30% shown on Page 100.

"Ole's" equations and values are as follows:

$$\text{Method 1} \quad R = (P - L)\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right) + Li \qquad \text{Eq. 1.}$$

$$\text{Method 2} \quad i = \frac{R - \dfrac{P - L}{n}}{P} \qquad \text{Eq. 2.}$$

$$\text{Method 3} \quad i = \frac{R - \dfrac{P - L}{n}}{\frac{1}{2}(P + L)} \qquad \text{Eq. 3.}$$

$$\text{Method 4} \quad i = \frac{1}{P/R} = \frac{R}{P} \qquad \text{Eq. 4.}$$

R = Annual net return, in dollars = \$3,000
P = Amount of investment in dollars = \$10,000
L = Final salvage valve, in dollars = \$0
n = Life of investment in years = 5
i = interest earned on investment (in decimal percent)

It will be noted that t = Interest earned by depreciation reserve is *not* mentioned. We shall have to *assume* values for it, if needed.

Since $L = 0$ in this problem (and is already assumed as such in the denominator of Eqs. 2. and 4.), and since

$$\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{1}{A_n}$$

in any good annuity tables, these equations can be simplified to read:

$$\text{Method 1} \quad R = P \cdot \frac{1}{A_n} \qquad \text{Eq. 1a.}$$

$$\text{Method 2} \quad i = \frac{R - \dfrac{P}{n}}{P} \qquad \text{Eq. 2a.}$$

$$\text{Method 3} \quad i = \frac{R - \dfrac{P}{n}}{1/2 \cdot P} \qquad \text{Eq. 3a.}$$

$$\text{Method 4} \quad i = \frac{R}{P} \qquad \text{Eq. 4. (unchanged)}$$

Substituting assumed values we get:

Method 1.

$$3000 = 10000 \cdot \frac{1}{A_n} \quad \text{or} \quad \frac{1}{A_n} = .3$$

which is true only when $i = 15.3\%$. But "Ole" should be warned that Method 1 assumes that i and t are identical in value. To clarify let us substitute

$$\frac{1}{S_n} + i \quad \text{for} \quad \frac{1}{A_n},$$

in which case

$$\frac{1}{S_n} + i = .3 \quad \text{and} \quad i = .3 - \frac{1}{S_n}$$

Now *assume* that t is not equal to i, but $= 10\%$. Then $i = .3 - .1638 = .1362 = 13.62\%$ instead of 15.3%.

Method 2. It is obvious that in this method $t = 0$. The depreciation reserve is locked up in the vault where it is safe enough but earns nothing; or it is used in the business—interest free. If this is *not* the situation Eq. 2. must *not* be used. However if $t = 15.3\%$,

$$i = \frac{3000 - \dfrac{10000}{S_n}}{10000} = .3 - \frac{1}{S_n} = .3 - .1483 = .1517 = 15.2\%$$

which is close enough to 15.3% for our purpose. *Or* if $t = 10\%$, $i = .3 - .1638 = .1362 = 13.62\%$.

Method 3. In this method "Ole" assumes that the *average* investment $= \frac{1}{2}P = \frac{1}{2} \cdot 10000 = \$5000$. Unfortunately "Ole" is wrong. The *average* investment over the five years is

$$\frac{10000 + 8000 + 6000 + 4000 + 2000}{5} = \frac{30000}{5} = \$6000$$

Making suitable correction we get:

$$i = \frac{3000 - \dfrac{10000}{5}}{6000} = \frac{3000 - 2000}{6000} = \frac{1000}{6000}$$
$$= .1667 = 16.67\%$$

This is somewhat more than 15.3% but close enough to indicate that Method 3 is a fairly accurate approximation provided that the average investment is correctly computed.

Method 4. In this method "Ole" assumes that an investor is happy to get his money back even if it has earned nothing in the 5-year period. If this is not true Eq. 4. should *not* be used. But suppose that R were sufficient to pay out in 5 years *after* paying i profit (or interest) on the investment. Then Eq. 4. would become

$$i = \frac{R - iP}{P}$$

whence

$$iP = R - iP \quad \text{and} \quad 2iP = R \quad \text{and} \quad i = \frac{R}{2P}$$

Substituting numerical values,

$$i = \frac{3000}{20000} = .15 = 15\%$$

which is close enough to 15.3%.

My final advice to "Ole" is: "If you *must* be a handbook engineer don't amuse yourself with the *apparent* inconsistencies of published formulas. Find out what they *really* mean, and compute accordingly. The similarity in numerical results will often astonish you!"—*Roland W. Pinger, Retired Colonel of Ordnance and Lecturer in Mechanical Engineering.*

AUTHOR'S COMMENTS

Since my allegorical former student, Ole, is no longer in this country, I guess I'll have to reply to Colonel Pinger's criticism of his work.

Frankly, I feel that the implication that Ole is a "handbook engineer" is hitting a bit below the belt. Because, you see, Ole did not attempt to ask what approximations *should* be used, but rather what methods *are* being used, here and now, in American Industry, and to examine their similarities and differences.

Let me document the fact that all of the methods Ole described are in current use, exactly as he described them.

Method 1 is, of course, that found in any standard text on Engineering Economy. None of these include Colonel Pinger's factor of "*t*"—nor is this necessary, if interest is defined as that rate of return earned while money is invested *in the project under consideration.* Under this definition, what is done with the depreciation reserve is irrelevant. (Incidentally, if the over-all return, including that on the earnings on the depreciation, is desired, the problem becomes much more complex than Colonel Pinger's solution would imply.)

Method 2, as Ole used it, and not as Colonel Pinger feels it should be used, is found in many places, such as in analyses of financial statements. I suspect that Ole's feeling was that its use was so common that its documentation was unnecessary. Since at least one reader does not seem to be aware of what seemed obvious to Ole, I guess I must apologize for his oversight in this matter and document it for him.

Among other places, this method is found in the derivation of the final formula used by G. A. Larson in an article entitled "When Does a Cost Savings Pay off," published in the March, 1956 issue of *Mill and Factory.* Another illustration of its use is on page 244 of Koepke's "Production Control," published by Wiley in 1941. Still another is in AMA General Management Series #183, by Charles Schwartz. If further documentation is required, see examples of the forms used by different companies on pages 15, 18, 20, and 40 of Conference Board Report "Controlling Capital Expenditures" (Studies in business policy, No. 62), published by the National Industrial Conference Board.

Since these users have all ignored Colonel Pinger's feelings that this method should not be used, it was appropriate, for Ole to comment on what was and is being done and determine the error in so doing.

Again, in examining method 3, Ole was clearly commenting on what *is* being done and not on what someone might feel *should* be done. In this case (perhaps because this method is less common) he had the wisdom to document its actual use in industry today. At the top of the second column of the original article, you'll find that this method—*exactly as Ole analyzed it,* is described in the Fall, 1956 *Engineering Economist.*

It is also interesting to note that, as Ole presented them, method 2 differs from method 3 (in the no salvage case) by a factor of exactly 2. If Colonel Pinger's correction to method 3, giving a more correct approximation to the average investment, is used, this factor changes to

$$\frac{2}{\frac{N+1}{N}}.$$

This means that if the good colonel used the same logic in method 3 as he did in method 2, his results should differ by this same factor—but they don't! The reason is that, in the first case, he insists on the inclusion of a factor "*t*" of 15.3% which yields a good approximation. But in the second case, where the logic of such an inclusion is identical, he omits this factor. Had it been included, the result would have been 25.3%—a much poorer approximation.

More important to the issue at stake, however, is the fact that Ole describes how a formula *is* used in industry where as Colonel Pinger describes how *he* feels it should be used.

This same argument holds for method 4. Although, to me, it would seem unnecessary, Ole also documented the use of this method. Perhaps this was because he realized that, to some readers, it would not be immediately apparent that this method was a very simple variant of the all-too-universal short pay off approach.

Speaking for myself, and not for Ole, I must confess that I can find no justification whatever for Colonel Pinger's "correct" version of this approach, or $i = \frac{R}{2P}$, except that it gives, in this case, a good answer. But let us consider another case. Suppose, *P*, as before, is 10000 and *R*, as before is $3000, but let *n* increase to 50 years. In this case the *true* rate of return by method 1 becomes 30%, and Ole's method 4 would also yield this result. But Colonel Pinger's "corrected" formula of $i = \frac{R}{2P}$, would give a result of 15%, or just half the correct value.

While the point is not an important one, I feel that I should perhaps comment on Ole's use of logarithmic paper which, by inference, Colonel Pinger criticizes. Ole asked me about this, and I advised its use, so that the range of values of interest could be included on a relatively small chart. I still think this was good advice. To limit the use of *any* type of chart to situations in which it produces a straight line is to waste many of its potential uses. If, as Colonel Pinger infers, this is faulty reasoning, the fault is mine, and not Ole's.

In summary, Ole set himself the task of examining differences obtained when using a number of methods of computing the return on invested capital. He chose to examine those methods found in use in industry today.

To say, as Colonel Pinger does, that some of these methods are, at best, approximations to the correct method is simply to restate my Norwegian student's conclusions in somewhat different form. To note, as Colonel Pinger does, that other approximation methods would yield other differences is, of course, a truism, but irrelevant.

If, in this reply, I have seemed overly partial to Ole's views, this should not be too surprising. After all, I said that I considered Ole a very capable student, indeed. Don't we all, to some degree, judge the capabilities of our students (and others) by the degree to which their ideas agree with our own?—*R. O. Swalm, Associate Professor of Industrial Engineering, Syracuse University.*

Institute Interests

CALENDAR

July 7-11: Nuclear Engineering Survey; Berkeley campus and Los Angeles (Westwood) campus, University of California. Write Nuclear Energy Programs, Engineering and Sciences Extension, Room 100, Building T-11, University of California, Berkeley 4, California.

July 21-August 16: Survey Research Techniques; University of Michigan Survey Research Center, Ann Arbor, Michigan. Write Survey Research Center, University of Michigan, Ann Arbor, Michigan.

August 11-22: The 1958 Statistical Methods in Industry Course; Los Angeles Campus, University of California. Write Edward P. Coleman, Coordinator, Statistical Methods in Industry Course, Department of Engineering, University of California, Los Angeles 24, California.

September, 1958: Fourth annual offering of the Engineering Executive Program starting in September; U.C.L.A. Write Engineering Executive Program, Department of Engineering, University of California, Los Angeles 24, California.

September 2-6: Third Annual Midwest Work Course on Plant Layout and Facilities Planning, University of Kansas, Extension Center, Kansas City, Kansas. Enrollment will be limited to 20 persons. Write: Midwest Work Course on Plant Layout and Facilities Planning, 4112 Eaton Street, Kansas City 3, Kansas.

September 8-19: Industrial Engineering Intensive Courses—Basic. The following courses are offered: Collective Bargaining for Engineers, Elements of Integrated and Automatic Data Processing, Engineering Economy, Materials and Processes of Manufacturing, Plant Layout and Materials Handling, Psychology for Engineers, Production Control, Quality Control, Tool Engineering, and Work Simplification and Measurement. Write Department of Industrial Engineering, Washington University, St. Louis 5, Missouri.

October 13, 14, 15: 1958 International Systems Meeting, Hotel Penn-Sheraton, Pittsburgh, Pennsylvania.

October 30, 31 and November 1: Northeastern Region AIIE Conference, Hotel Syracuse, Syracuse, New York. Write: Mr. Schuyler Jackson, c/o Continental Can Company, 1016 East Water Street, Syracuse 3, New York.

November 10-14: Third Annual Paperwork Simplification Conference, University of Dayton, Dayton, Ohio. Write: John B. Steinbruegge, Associate Director, Division of Specialized Educational Services, University of Dayton, Dayton 9, Ohio.

April 5-10, 1959: Nuclear Congress, Cleveland, Ohio, sponsored by all engineering societies. Write: T. A. Marshall, Jr., 1959 Congress Manager, c/o Engineers Joint Council, 29 West 39th Street, New York 18, New York.

ANNOUNCEMENT

It is with pleasure that we report officially that at a meeting of the Executive Committee of Engineers Joint Council, held on February 21, 1958, the following was recorded for the record:

"Membership—F. D. Kay, Chairman. The Secretary reported that the following member societies of EJC had reported favorably on the application of the American Institute of Industrial Engineers for a change in status from Associate to Constituent Member:

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"This information was reported for the record, and as the necessary two-thirds majority vote has been received, the Executive Committee recognized the American Institute of Industrial Engineers as a Constituent Society as of this meeting.

"We are advising Professors A. W. Rathe and F. M. Gryna . . . that they are now recognized as the representative and alternate respectively for the AIIE on the EJC Board of Directors."

FIFTH ANNUAL SOUTHEASTERN REGIONAL AIIE CONFERENCE

The Fifth Annual Southeastern Regional AIIE Conference was held in Pensacola, Florida, on May 8 and 9, 1958. The University of Florida Student Chapter and the Pensacola Senior Chapter joined forces to sponsor the most outstanding conference yet held in the Southeast. Registered attendance totaled 130 making possible a net profit of $1,500.00 to be split equally between the Pensacola Chapter and National.

The conference got off to a fast start with a Social Hour and advance registration on Wednesday night, May 7th. The site of the first day's proceedings was the Officer's Club of the Pensacola Naval Air Station where James T. French, current Vice President of the Southeastern Region, welcomed the conferees. The first paper, entitled, "The AIIE—Its Contribution to Scientific Management," was presented by Floyd J. Titler, AIIE Executive Secretary. Mr. Titler pointed out that since the concerns of both management and Industrial Engineers are closely related, the American Institute of Industrial Engineers contributes to scientific management by contributing to the improvement of Industrial Engineers. It was further pointed out by Mr. Titler that Industrial Engineering is concerned with the design, improvement and installation of systems of materials and equipment and scientific management is concerned with the operations of these systems.

Following Mr. Titler with the second paper was David S. Chambers, Consultant in Industrial Statistics, of Industrial Controls, Inc., Knoxville, Tennessee. Dr. Chambers discussed "Some Statistical Techniques Useful In Industrial Engineering."

Concluding the first morning's sessions was Mr. R. A. Harrison, International Business Machines Corporation, Atlanta, Georgia. Mr. Harrison presented many interesting facts on "Systems Requirements Prior to Mechanization."

Lunch was served at the Officer's Club at which time the conference was officially welcomed to the Naval Air Station by Admiral Carson, Chief of the Naval Air Training Command, Pensacola, Florida. Immediately following the luncheon, the conferees were treated to a tour of the Naval Air Station Overhaul and Repair Department and witnessed a fire fighting demonstration and an air-sea rescue demonstration.

Marking the halfway point of the conference was a banquet Wednesday night. Frank J. Johnson, AIIE First Vice President, did an outstanding job as Master of Ceremonies. Jerome Barnum, Director of Jerome Barnum Associates, Scarsdale, New York, delighted the capacity crowd with a very enjoyable presentation of "Humanics of Industrial Engineering." Barnum said the problem posed by the present recession should point up the vital necessity

for a better understanding of human motivations. Business and management, Barnum continues, have made the mistake of trying to change the people to fit the needs of the business, instead of changing the business to meet the needs of the people.

Jim T. French was honored at the banquet as the most outstanding Industrial Engineer in the Southeastern Region for the year 1957-58. Jim received this award for his outstanding contributions to the AIIE and the field of Industrial Engineering. The award consisted of a scroll and an engraved ceramic beer mug which will serve as a reminder of Jim's outstanding achievements in Industrial Engineering.

Friday, May 9th, the last day of the conference, was a particularly interesting day with a wealth of information being presented. Dr. R. N. Lehrer, Chairman, Industrial Engineering Department, Northwestern University, presented "The Challenge of Industrial Engineering—Operations Research" as the fourth paper.

Dr. Lehrer was immediately followed by Mr. F. J. Carr with "Simulation Techniques In Production and Inventory Control." Mr. Carr is a Staff Assistant of the Production and Inventory Control Department, Westinghouse Electric Corporation.

Mr. Dan C. Doulet, a past president of the Pensacola Chapter, and presently with Doulet-Reed Associates in Knoxville, Tennessee was the third speaker of this last day of the conference. Mr. Doulet presented many interesting views on "Selling Industrial Engineering to Management."

Immediately following the luncheon, Mr. W. F. Hyde, Manager of the Southeastern Region of the H. B. Maynard and Company, Fort Lauderdale, Florida, gave several unusual approaches for "Application of Industrial Engineering to Maintenance."

Mr. Earl B. Mills, Plant Accountant, The Chemstrand Corporation, Pensacola, Florida, was next on the program with a discussion on "Return on Incremental Investments." Mr. Mills was followed by W. G. Preusell, the last speaker of the conference. Mr. Preusell, Assistant Superintendent of Wage Practices, Western Electric Company, Winston-Salem, North Carolina, gave his views on "The Industrial Engineer's Place in Modern Wage Administration."

The conference closed with a business meeting of the Chapter Presidents in the Southeastern Region.

ATLANTA CHAPTER

The 1957-58 year has been a busy and successful one for the Atlanta Chapter. The Chapter programs were varied. They included speakers from labor and management presenting both sides of industrial problems, a talk on the problems of the industrial development of Georgia, a plant tour of the Atlanta Paper Company and a meeting with the officers of the Student Chapter of AIIE from Georgia Institute of Technology. The last meeting of the year was the customary "Ladies' Night" at which Dr. Harrison, President of Georgia Tech, spoke on the "Advances that Engineering Will Make in the Next Twenty Years."

The Chapter is also proud of being one of the nine chapters of AIIE winning the Award of Excellence. Its members have worked hard this year publishing a program schedule a year in advance, increasing membership by 41%, conducting a refresher course for the Professional Engineer's Examination, and starting a membership manual which will include pictures and short biographies of the members. In addition to these activities, the members have also been busy with the planning for next year's National Convention which will be held in Atlanta May 14-16, 1959. The Chapter hopes to make this convention a notable one. "Y'all come."

The Chapter expresses its appreciation to the retiring President, Milt Pitts, of Lockheed Aircraft Corporation, and his hard-working officers for an excellent job. The new President, John Scott, of the Showerdoor Company of America, and his officers will undoubtedly carry on the fine work.

BOSTON CHAPTER

The Boston Chapter opened its 1957-58 season with its entire year's program of dinner meetings and seminars completely established and confirmed. This was significant in showing that if the program committee begins its functions early, preferably early in the summer, it can solidify the program before the season's activities commence. Because of the early start, the Boston Chapter was able to publish both a calendar and a booklet showing all its activities.

The schedule was as follows:

October 18, 1957—Seminar
- Subject—Cost Reduction and Cost Control Clinic
- Leader—Phil Carroll, Consultant
- (Jointly sponsored by Boston and Merrimac Valley Chapters)

October 21, 1957—Dinner Meeting
- Speaker—Dean Gordon B. Carson, National President, AIIE
- Subject—New Concepts in Industrial Engineering

November 18, 1957—Dinner Meeting
- Speaker—David Lasser Research Director, IUE-CIO
- Subject—Union's Attitude Toward Automation

November 19 to December 17, 1957—Seminars and Round Tables
- Subject—The Latest Techniques of Practical Plant Layout
- Leader—Marshall Schneider, Industrial Engineer, Walworth Company.

January 20, 1958—Dinner Meeting
- Speaker—Warren Alberts, Director of Industrial Engineering, United Airlines
- Subject—Industrial Engineering and Operation Research

February 17, 1958—Dinner Meeting
- Speaker—H. Ford Dickey, Manager of Production Control Systems, General Electric Company
- Subject—New Techniques in Production and Inventory Control

March 17, 1958—Dinner Meeting
- Speaker—Raymond Villers, Consultant, Rautenstrauch and Villers
- Subject—Effect of Computers on Industrial Organization

April 21, 1958—Dinner Meeting
- Speaker—Professor James Bright, Harvard Business School
- Subject—Communication Devices as an Aid to Materials Handling and Production Control

May 19, 1958—Dinner Meeting
- Speaker—W. C. Cooling, Director of Industrial Engineering, Baker & Co.
- Subject—Front Line Cost Administration through Methods Analysis

In addition to the above meetings, six plant tours were scheduled.

The Boston Chapter has also been very active in several local engineering community activities.

Under the coordinating efforts of the Engineering Societies of New England, the Boston Chapter has been serving on the committee, which is sponsoring a bill before the Massachusetts State Legislature for the mandatory registration of professional engineers.

In addition to this the Boston Chapter participated on the planning committee and activities relative to National Engineers' Week, providing speakers who addressed over one thousand high school students at several high schools in and around Greater Boston.

CHARLESTON-HUNTINGTON CHAPTER

This being our first article for publication in our National Journal, it might be of some interest to tell of our birth and growth.

On March 22, 1956, Mr. Charles Howard, Chief Plant Industrial Engineer for The American Viscose Plant at Nitro, W.Va., with the assistance of friends in Huntington and Charleston, W.Va., called an informal dinner meeting of Industrial Engineers in the Charleston-Huntington area for the purpose of talking over the possibility of organizing a Charleston-Huntington Chapter of AIIE. There were thirty-eight engineers present at this meeting who, after hearing Dr. S. Kyle Reed, board member of national AIIE, speak on the purpose and function of the AIIE, voted unanimously to take steps to form a joint chapter. On May 24, 1956, our chapter received its charter (#58). The presentation was made by Mr. Ralph Updegraff, Vice President of the Central Region, who gave us several ideas of organization and objectives of chapter. Permanent officers were elected at this time and we were in business with a charter membership of 22. Our membership has grown to a total of 57 with several applications in process at national headquarters.

Although Huntington and Charleston are 50 miles apart, mutual interest has been such that our average attendance has been approximately 60% of the membership. The monthly meetings are held alternately in Charleston and Huntington. This plan works fine except during the summer when Charleston is on Daylight Saving Time and Huntington on Eastern Standard Time. Some of the Charleston members find it hard to wait until 7:30 to eat.

We, like most other chapters, publish a monthly newsletter outlining the program for the next meeting plus any information pertinent to the chapter.

Several interesting plant tours have been made in our area and we have had the honor of having as our guest and speaker Dean Gordon B. Carson, President of the AIIE.

We are all looking forward to our May meeting which has been designated as ladies night. Great things are being planned for the distaff side.

The chapter owes it rapid growth to the untiring efforts and ability of our first president "Chuck" Howard, and the continuing interest and efforts of the present officers. We wish to extend an invitation to all members everywhere to attend our meetings if they happen to be in the area on the third Monday of the month.

Our chapter has recently become a participating member of the Tri-State Technical Societies Council of Huntington, W.Va., and the Kanawha Valley Technical Council of Charleston, W.Va.

Our present officers are:

President—Robert Wesson, Carbide & Carbon Chemicals Co., S. Charleston, W.Va.
Vice President—W. L. Emmert, International Nickel Co., Inc., Huntington, W.Va.
Secretary—William Mahaffey, Carbide & Carbon Chemicals Co., S. Charleston, W.Va.
Treasurer—Harry B. Stump, True Temper Corporation, Charleston, W.Va.

CLEVELAND CHAPTER

The February meeting of the AIIE was held on February 6 at Hotel Cleveland. A most enlightening discussion on a most delicate phase of Industrial Engineering was presented: "The Manager Looks at Union-Industrial Engineer Relations," by Paul Bruhn, Manager of the Berger Division of the Republic Steel Corporation. Within the limits of propriety, Mr. Bruhn presented both sides of this important topic—the viewpoint of the union, and that of management. The speaker displayed poise and thoughtfulness. He attended Bethany College, and has worked as an Industrial Engineer, plant superintendent, assistant plant manager, and at present, Manager of the Berger Division of the Republic Steel Corp.

The March meeting of the AIIE was held on March 6 at Hotel Cleveland. The large audience in attendance was privileged to hear George Gustat, Director of Industrial Engineering at the Eastman Kodak Company, discuss "Administrating the Industrial Engineering Functions." Mr. Gustat started with the early history of Mr. Eastman and the founding of his now world-famous company. He attributes their tremendous success to effective top management, excellent staff work, good personnel, and an excellent training program. He introduced the administration of Industrial Engineering at his company with an explanation of the status and function of their IE department; how they select and control their work projects, and how they rate and appraise their engineers. All their staff functions are purely advisory, he said. Mr. Gustat, who was educated as a chemical engineer at the University of Illinois and has worked in many technical phases of the Eastman firm, presented the departmental structure of their organization via 35 mm. slides. He has authored many articles, lectured at many leading universities, and is active in several professional societies, including the AIIE at Rochester.

COLUMBUS CHAPTER

The Columbus Chapter's annual "Ladies Night" function was a dinner meeting at the "Desert Inn" on January 28, 1958. The highlight of the evening was Richard J. Anderson's, stimulating discussion of "Space Travel." Mr. Anderson is Assistant to the Director of Battelle Memorial Institute and is one of the most sought after speakers in the Central Ohio area.

On February 18, 1958 the Time Study Special Interest Group held a meeting in the Industrial Engineering Building of The Ohio State University. The meeting consisted of a panel discussion of the factors which determine the choice or selection of a measurement method in standards setting.

The subject for the February Chapter Meeting was "Automation at Work." The meeting was held on the 25th in the Conference Room of the Columbus Coated Fabric Company. Mr. R. W. Choats, Zone Manager, Central Region, Mechanical Handling Systems, Inc., was the speaker. His interesting discussion was supplemented by sound, color films on actual automated operations at work.

The March meeting of the Time Study Special Interest Group was at the Ternstedt Division Plant of General Motors Corp. The program topic was "Work Sampling." The use of random sampling was demonstrated and discussed as the basic concept in work sampling.

The Materials Handling Special Interest Group had a dinner meeting followed by a conducted tour at the F. & R. Lazarus Company on March 20. Mr. John Shea, Superintendent of Buildings and Merchandise Handling, planned and conducted the very interesting tour of the "behind the scenes" operations of this large department store.

The Ninth Annual AIIE Conference sponsored by the Columbus Chapter was held at the Southern Hotel, Columbus, Ohio, March 29, 1958.

Mr. Allan H. Mogensen, of the famed Lake Placid, New York, Work Simplification Conferences, conducted the conference. The theme was "Work Simplification" A Top Management Philosophy.

Topics covered in the conference were The Philosophy of Work Simplification, The Tools and Techniques of Work Simplification, How to "Set Up" and "Sell" a Work Simplification Program and Benefits of a Work Simplification Program.

Dean Gordon B. Carson, National President of the AIIE and a member of the Columbus Chapter was selected as the Technical Man of the year of Central Ohio by the Columbus Technical Council. The Ohio State University Educator was chosen for the honor on the basis of his outstanding career as an Executive and

Engineer in private industry and as a College Educator and Research Worker. This is a great honor for Dean Carson as well as the AIIE.

At the April Chapter meeting held in the Physics Building on the Ohio State University Campus, Mr. James M. Apple, author and nationally known personality on the Plant Layout Field, spoke and showed slides on the subject "Planning and Implementing the Production Flow Pattern." His extremely interesting presentation showed us many of the points to be considered from the planning of the factory location to the setting up for the finished product.

DETROIT CHAPTER

Our third annual dinner meeting was held May 13, at the Engineering Society of Detroit. The principal speaker was Dr. Ralph Lee. Dr. Lee spoke on "Personalities in Business." The talk was based on humorous incidents in the lives of prominent business people.

This was the most important meeting of the year because it was election night. The incoming officers will have an imposing record of achievement, resulting from the efforts of the outgoing officers, to surpass. During the past year the first Chapter Conference was held; the Chapter accepted the responsibility for the National Resolutions and Award Committee; and our membership increased approximately 25 percent. Congratulations are due the outgoing officers for their splendid record.

Naturally, we are anticipating the next year to be even better. Plans are already being made for the Second Conference, and there should be another increase in membership. We realize that the Detroit area has the potential to be one of the largest chapters in the country and every effort will be made to make it the largest.

LOS ANGELES CHAPTER

The February meeting of the Los Angeles Chapter featured a technical clinic followed by two speakers.

The first guest speaker was Dr. Richard Bellman, mathematician with the Rand Corporation, whose topic was "Digital Computers and Experimental Mathematics."

Dr. Bellman has had an extensive background in academic and wartime defense activities. He has published one hundred and seventy research papers, two books—*Stability Theory* and *Dynamic Programming*, and five monographs. He is currently a consultant for A.E.C. and for Booz, Allen and Hamilton.

Our second speaker was Frank Cross, Industrial Engineer with North American Aviation, whose topic was "Industrial Engineering in the Far East." Mr. Cross has worked on Time Study, Wage Incentives, Job Evaluation, and Methods Analysis. His talk covered the problems of establishing an F86F assembly plant in Nogoya, Japan, and was illustrated with fifty slides.

The first speaker at our March meeting was Dr. E. W. Paxson of the Rand Company, who spoke on "Operational Gaming from the Military Point of View." Dr. Paxson told how the Air Force uses the technique of gaming to prepare for possible emergencies. He made suggestions as to how industry could adopt this technique.

The second speaker was Reno Cole, visiting Professor of Engineering at U.C.L.A., whose subject was "Increasing Utilization of the Cost Quantity Relationship in Manufacturing." Mr. Cole gave the results of an investigation into the use of the learning curve by firms in and out of the aviation industry.

Our next meeting was held April 8, at the Rodger Young Auditorium, 936 West Washington Boulevard.

The first speaker was Mr. Jack Vance of McKinsey and Company, whose subject was "There Is Plenty of Room at the Top."

The second speaker was Mr. A. L. Chilman, Works Industrial Engineer with U. S. Steel and Western Regional Vice President of AIIE, whose topic was "Industrial Engineering—an Aid to Management."

LOUISVILLE CHAPTER

Dr. William Gomberg was the guest speaker at the February meeting of the Louisville Chapter of AIIE. This was the best attended meeting ever held by our chapter with 105 members and guests in attendance. Dr. Gomberg, who was Industrial Engineer for the International Ladies Garment Workers Union for several years and is now a professor of Industrial Engineering at Washington University of St. Louis, said that the reason for the change of positions was not because of a change in his philosophy, but rather was due to the lack of a challenge in today's unions. The thrill of fighting for $3.00 per hour for a man already making $2.90 is not nearly as exciting as fighting for the right to organize a subsistence wage. It is now pretty well agreed that organized labor is not a challenge to our industrial culture, but is rather the required check and balance.

The Research Committee of the Louisville Chapter, AIIE, has recently completed a survey of Industrial Engineering practices in the Louisville area. Replies were received from 19 manufacturing companies in this area. A copy of the results of this survey is included with the news letter to all members of this AIIE chapter.

Mr. H. J. Macemon of the Dishwasher and Disposal Department of General Electric spoke at our meeting on March 19 at Bellarmine College. His subject was "Brainstorming." He defined creativity as that quality of the human brain that electronic computers don't have. Everyone is born with creative ability but very few people use very much of it. Most children use their creative ability, but its use becomes restrained in school. There are ways to regain creativity. A person who can be trained to use his creative ability must have an active and inquisitive mind, constructive discontent motivation, self confidence, a gambling instinct, and a willingness to discard that which exists. Brainstorming is to be used in only one area, searching for solutions, and is only one of many methods which can be used. It only gives ideas which must be further developed. One reason that it has received adverse criticism is that it is not placed in its proper perspective. Some users expect a cure-all which will do the whole job. In order to be effective, a brainstorming session must have no negative thinking, no evaluation, a large quantity of ideas, a building on others' ideas and complete free wheeling—the wilder the ideas the better. The meeting then turned into a brainstorming session to get ideas for programs for the AIIE meetings next year.

"The Foreman's Role in Cost Reduction" was presented on April 8 at Bellarmine College. Mr. Bleick Von Bleicken and Bill Welsh of "Institute of Modern Management" handled the seminar. The Luncheon speaker was Dr. J. S. Long and the Dinner speaker was Dean Gordon Carson, National President of AIIE.

MEMPHIS CHAPTER

The April meeting of our chapter was held at the Highland Heights Branch of the Union Planters Bank on April 16. Prior to the regular meeting, a Director's Meeting took place. Mr. Ralph W. Vaughan was guest speaker of the evening. Mr. Vaughan is the Manager of the Commercial and Industrial Engineering Department of the Memphis Light, Gas, and Water Dept. As a member of the Memphis Industrial Development Commission, he recently visited the Detroit area. His mission was to interest industry in the Detroit area to recognize the benefits of settling in the Memphis area. Mr. Vaughan spoke on his experiences in Detroit. A question and answer period followed his speech.

Hancel Bonds, our Vice President, deserves our respect and admiration for the superior job he did during National Engineers Week. He was in charge of displays depicting the Engineering

Progress and if you visited the Main Street area during Engineers Week you saw samples of his work.

It might be well to mention at this time that the State of Tennessee recognizes and provides facilities for Professional Registration of Industrial Engineers. Joe Maloy made a report to the National Chairman of Professional Registration during the week of March 15. It is significant to note that our Society has only one registered.

MID-HUDSON CHAPTER

The Charter presentation dinner of the Mid-Hudson Chapter was held on February 20, 1958 at the Nelson House, Poughkeepsie, New York. Over forty members and their wives attended the dinner-meeting. Mr. Floyd J. Titler, executive secretary, AIIE, presented the Charter and welcomed us, the 76th Senior Chapter of AIIE. He addressed the group on "The AIIE Organization." Dr. Alex W. Rauthe, AIIE board member-at-large, installed the newly elected officers.

Despite the worst possible winter conditions the March meeting attracted over 20 members to hear Mr. John Arwood, a materials handling engineer, from Union Carbide, Bakelite Division speak on "The Development of a Bulk-Handling System for Solids." The problem of handling 10,000# of polyethylene pellets from manufacturer to consumer was solved by employing a rubber cylindrical container, 7½ feet in diameter and height. Also involved was the design of special loading, unloading and transporting equipment and cost justification.

The April meeting was addressed by Dr. Neil Bowman, staff speaker for the National Association of Manufacturers. His talk "Changes and Challenges" was lively and thought-provoking; covering the progress of man by engineering, human engineering and sales imagineering. Proper application of these tools will enable the engineer to meet the challenge of the future.

Other meetings to date have covered the following topics: "Cost Reduction"—one company's cost reduction program, Impact of Improvement"—relationship of the Industrial Engineer and management, and "AIIE"—an outline of the AIIE's organization and program. Heinz A. Burmester and Donald A. Leard, co-chairmen of the program committee, arranged this interesting series of meetings.

For the May meeting of the chapter, a plant tour of the Western Printing and Lithographing Company, Poughkeepsie, New York was arranged. This meeting will conclude the chapter's activities for the 1957-58 season. Our meetings, which resume in September, are held in Poughkeepsie, New York at 7:30 P.M. on the third Thursday of each month at the Central Hudson Auditorium, 47 Cannon Street.

Newly elected officers of the Mid-Hudson Chapter, American Institute of Industrial Engineers (left to right), D. A. Leard, Treasurer, Saugerties, New York; W. D. Wilson, President, Saugerties, New York; L. G. Smiley, Vice President, Poughkeepsie, New York; J. Saltzman, Secretary, Peekskill, New York; standing, G. Snyder, Director (2 yr.), Poughkeepsie, New York; B. Blemker, Director (1 yr.), Hurley, New York; and R. Reip, Director (1 yr.), Wappinger Falls, New York; J. Hecker, Director (2 yr.), Peekskill, New York, not present.

The Chapter was chartered to the Advisory Council for Scientific Education in the Mid-Hudson area on April 17, 1958. In this capacity the chapter will be called upon to aid in educational programs and development. This was accomplished through the efforts of the Student Relations Committee headed by Robert Reip.

Since its organization in October, 1957, the chapter has grown to 39 members with 4 applications in process. Our goal is to attain 50 members by the end of our first year.

PHILADELPHIA CHAPTER

"Quality Control and the Industrial Engineer" was the subject of the lecture presented to the Philadelphia Chapter by Mr. John V. Hart on Wednesday evening, March 19. Mr. Hart is Manager of Inspection and Quality Control at Brown Instruments Division of the Minneapolis-Honeywell Regulator Company in Philadelphia. He has been with the firm for 24 years and had been active in the American Society for Quality Control and the American Institute of Electrical Engineers.

In addition to those members and guests present from the Delaware Valley area, we were honored to have in the audience a group of quality control specialists from Spain. These men were touring the country as part of an educational exchange program and happened to be visiting our city at the time of the AIIE meeting. Although few of them could speak English, they were able to listen to the lecture through an interpreter who translated the lecture as it was being presented.

Mr. Hart's discussion covered the following topics: 1. Fundamentals of Quality; 2. Planning for Quality; 3. What Quality Control can do for Industrial Engineering; 4. What Industrial Engineering can do for Quality Control. As aids to his presentation, Mr. Hart used color slides and mimeographed notes which were distributed to the audience to illustrate some of the more significant aspects of the material. After the formal presentation, questions were received from the audience.

Inclement weather plagued our activities during the fall and winter. In addition to the occurrence of snowstorms on several of our meeting nights, we encountered severe rainstorms on the occasion of our two plant visitations. The first was to the Scott Paper Company in Chester, Pa., on January 29. Our second trip was made to the Standard Pressed Steel Company in Jenkintown, Pa. Both trips were well attended despite the adverse weather conditions.

Our annual business meeting was held at the Engineer's Club in Philadelphia on March 16. The newly elected officers for the 1958-59 year were announced as follows: President, Luther A. Darmstaetter, Chief Industrial Engineer, Congoleum Nairn, Inc.; Vice-President, Arno Cassell, Assistant Industrial Engineer, Merck Sharp & Dohme, Division of Merck & Co., Inc.; Secretary, Richard W. Walton, Senior Industrial Engineer, Merck Sharp & Dohme, Division of Merck & Co., Inc.; Treasurer, Felix S. Miksis, Ind. Eng. Cost Estimating Supv., Minneapolis-Honeywell Reg. Co.

PITTSBURGH CHAPTER

The Pittsburgh Chapter of the AIIE has been very active for the 1957-58 season. Stimulating and thought provoking discussions were directed by the following individuals who participated in the monthly meetings.

October Meeting—F. J. Titler, Assistant Chief Industrial Engineer for Republic Steel Corporation, and Executive Secretary of

the American Institute of Industrial Engineers—Subject: "AIIE Organization" and "Work Simplification."

November Meeting—P. M. Matthews, Director of Manufacturing, Apparatus Division, Westinghouse Electric Corporation—Subject: "Engineering Profit into the Product."

December Meeting—A. G. Holzman, Associate Professor of Industrial Engineering, University of Pittsburgh—Subject: "Is Operations Research for the Industrial Engineer."

January Meeting—W. M. Aiken, Vice-President of H. B. Maynard and Company, Inc.—Subject: "Use of Methods-Time-Measurement in the Development of Universal Maintenance Standards and Universal Office Standards."

February Meeting—J. M. Walton, Assistant to Works Manager of Midland Works, Crucible Steel Company—Subject: "Maintaining Incentive Plans—A Case History."

Plans were completed for a series of three seminars involving actual Industrial Engineering case problems. The seminar program follows.

March 12, 1958—"Day Work Methods Changes and Incentives," Discussion Leader, Thomas W. Slovick, Chief Industrial and Works Manager, Edwin L. Weigand Company.

April 9, 1958—"The Problem of Methods Changes and Obsolete Standards," Discussion Leader, Dewey G. Denman, Superintendent of Industrial Engineering, Power Circuit Breaker Department, Westinghouse Electric Corporation.

May 14, 1958—"Development of Wage Incentives for Maintenance Workers," Discussion Leader, Andrew N. Costas, Assistant Plant Industrial Engineer, Homestead District Works, United States Steel Corporation.

All of these sessions were conducted in Engineering Hall on the University of Pittsburgh campus.

The following members were elected to office for the 1958 term: President, Paul D. O'Donnell, Westinghouse Electric Corp.; Vice-President, Andrew N. Costas, United States Steel Corp.; Secretary, Victor R. Kazmierski, Westinghouse Electric Corp.; Treasurer, Richard A. Dudek, University of Pittsburgh; Directors, R. B. Hewitt, Crucible Steel Company; J. G. Benz, Allegheny Ludlum Steel Corporation; W. R. Turkes, University of Pittsburgh; S. O. Rider, Allegheny Ludlum Steel Corporation.

SAVANNAH CHAPTER

Professor Earl P. Martinson, Head Professor, Industrial Engineering Department, University of Florida, gave a very interesting talk on the subject, "Industrial Engineering as a Profession." Professor Martinson noted that commerce today offers a number of responsibilities in the area of Industrial Engineering. It was stressed that unless qualified Industrial Engineers maintain a high level of proficiency in all techniques and make themselves available to meet this responsibility, it will fall in the hands of opportunists.

Another recent meeting was held at the Southern Nitrogen Company, Inc., where we were treated to a flow process chart explanation of the process and a guided tour of the brand new installation.

"Human Aspects of Industrial Engineering" was the subject of the April meeting with Mr. E. B. Baker, Regional Personnel Manager of Cluett, Peabody Company of Atlanta, as speaker. Mr. Baker poignantly stressed the need for a continual awareness of the importance of human relations in Industrial Engineering and noted that in many instances, the Industrial Engineer is held in low regard by employees as a characteristic of his assignment. While it was noted that the Industrial Engineer frequently is in an undesirable position because of his assignment, it is the responsibility of the individual engineer to handle himself in such a way as to avoid the pitfalls of that situation.

Discussing Mr. Baker's recent address to the Savannah, Georgia, Chapter of AIIE are L to R: Mr. E. B. Baker, Regional Personnel Manager for Cluett, Peabody and Company of Atlanta; Mr. James A. Henderson, Division Industrial Engineer for Union Bag-Camp Paper Corporation and Vice-President of the Savannah AIIE Chapter, and Mr. Rudy B. Roessle, Plant Manager of Rathborne-Hair and Ridgeway Box Company and President of the Savannah Chapter.

SEATTLE CHAPTER

The March meeting of the Seattle Chapter was devoted to the award of prizes and the reading of the winning papers in the Chapter's second annual technical paper contest. The winners and titles:

First Prize: Prof. Berl Owens, University of Washington, "Random Work Sampling—Is It Representative?"

Second Prize: Elliott DeForest, Partner, Joseph B. Ward & Associates, Management Consultants, "People Are Funny—the Human Factor in Engineering"

Third Prize: Bert Pound, Boeing Airplane Co., Transport Division, "Profit with Personality—Are We Neglecting the Personality Requirements of our Employees?"

Fourth Prize: A. J. Rorstad, Boeing Airplane Co., Seattle Division, "Noise—Its Effect on Production Efficiency and the Employees"

The April meeting inaugurated "Bosses Night." Many members persuaded their bosses to turn out for this meeting, to rack up the largest attendance of the year. The members and guests were well repaid by a stimulating and informative talk by Mr. C. Morrison Johnson, President of Washington Metal Products Company, Tacoma, Washington. Mr. Johnson spent a year in Europe as a member of a team sent by the International Cooperation Administration to explain marketing methods to foreign industrialists. Seminars were held all over Western Europe, and in Yugoslavia, and Mr. Morrison has brought back a perceptive account, enlivened by many personal experiences of both an amusing and alarming nature.

Our fourth annual Cost Reduction Conference was held in Seattle, Washington on April 18 and 19. The Conference had a paid registration of almost 250 people, was a financial success for the Chapter, and inevitably added to the prestige of Industrial Engineering in the Area.

For the second successive year, emphasis in the program was on prominent outside speakers, which included:

Robert E. Williams, Disogrin Industries, Inc., of Jamaica, N.Y., speaking on "Hidden Waste"

Mr. Richard Felver, Consultant Designer, Carnegie Institute of Technology, on "Product Planning"

Mr. Douglas Watson, McKinsey & Co., San Francisco, Calif., on "Inventory Control"

Mr. Joseph B. Meier, Council of Profit Sharing Industries, Chicago, Illinois, "Profit Sharing Plans-Boon or Bane"

Mr. Spencer A. Tucker, Martin & Tucker, Consultants of Little Neck, New York, on "Profit Planning"

Mr. A. L. Chilman, Vice-President, Western Region, AIIE, on "Management Use of Industrial Engineers"

Mr. H. B. Maynard, President, Methods Engineering Council, Pittsburgh, Pennsylvania, on "Work Measurement"

We wish to second the remarks of the Great Salt Lake Chapter in the March-April JOURNAL—it does not take a large chapter to put on a successful meeting. It does take a lot of planning and hard work. Chairman of this fourth conference was Mr. Jerry Watson, Boeing Airplane Co.

WINSTON-SALEM CHAPTER

The January meeting featured Col. Frank F. Groseclose, Director of the School of Industrial Engineering at Georgia Tech and past National President of AIIE. "The Future of Industrial Engineering" was foreseen as both benefiting from and contributing to the continued advances of the American economy. However, he stated such growth would not develop without constant application of engineering principles and without constant cost awareness by management.

Dr. A. V. Feigenbaum, Manager of Quality Control Service for General Electric Company, was the guest speaker at the February AIIE meeting. Over 110 engineers and guests representing 15 industries attended a dinner meeting to hear Dr. Feigenbaum's address, "The New Total Quality Control." His talk was based on the theme, "Producing a Quality Product is Industry's Key to a Sound Competitive Position and Profit Potential." Competition in America is fully as much competition of quality as it is competition of price."

The annual Motion and Time Study Conference sponsored by the Winston-Salem Chapter of AIIE and the Greensboro Chapter of SAM opened March 20 with an evening social period for members, students and guests. The all-day program of lectures and discussions was held March 21 with five distinguished industrial and professional leaders as principal speakers. Mr. Hadden S. Kirk, Vice-President of Manufacturing for R. J. Reynolds Tobacco Company, opened the program extending a welcome to the conferees. Harold Robinson, President, Greensboro Chapter, SAM, presided over the morning meetings and Herman L. Cook, President, Winston-Salem Chapter, AIIE, presided over the evening session.

The morning speakers were Richard M. Crossman, Vice-President of Serge A. Birn Company, Louisville, Kentucky, who spoke on "Master Clerical Data—A New Approach to Office Cost Reduction" and R. Wade Lindsay, Operations Research Consultant, American Enka Corporation, Enka, North Carolina who spoke on "Operations Research in Action." The afternoon speakers were C. G. Fultz, Director of Applied Science, International Business Machine Company, Atlanta, Georgia, who spoke on "Computing Horizons in Time and Motion Study," and Joseph F. Lindsey, Associate Professor, Department of Industrial Engineering, VPI, Blacksburg, Virginia, who spoke on "The Future of Time Study." R. W. Grupenhof, National Director of the Greensboro Chapter of SAM presided over the evening meeting. James King, Vice-President, Burlington Industries, Greensboro, North Carolina, presented the closing lecture of the conference. He discussed, "The Effective Use of Industrial Engineers by Management."

The April meeting was held on the 24th with Clark B. Kingery, Assistant Personnel Director for the Hercules Powder Company of Wilmington, Delaware, as the guest speaker. His subject was, "Human Relations in Industry." He emphasized the fact that progress is tied directly to creative thinking—an understanding among people is an aid to this thinking. He pointed out that there is "no more important job in your life, work or success than human relations." New officers were elected at the business meeting. A. J. Davis, currently serving as Vice-President, was elected President, succeeding H. L. Cook.

Other officers are C. M. Dunlap, Vice-President, R. W. Williams, Secretary, and O. R. Armstrong, Treasurer. New directors are C. T. Johnston and H. G. Worley.

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Research Abstracts

July 1952—July 1957

The following research abstracts represent a partial listing of research related to Industrial Engineering that was performed during the July 1952 to July 1957 period. This information was organized by the AIIE Research Information Committee from materials furnished by various organizations conducting research. It does not represent an exhaustive listing, for not all research has been reported. Additional abstracts will be reported at a later date. Plans are being made to obtain and publish additional abstracts for the period currently being reported, for the period prior to July 1952, and for current research on a yearly basis.

The Research Information Committee has made no attempt to judge the merits of any research report. It has collected, eliminated "application" articles, and classified the reports according to the categories used by the AIIE Director of Research and the Research Committees. Reports were considered to be "application" when existing theory and/or technology was utilized to solve a specific problem without advancing a new or unique and generally applicable concept, theory, hypothesis or technique. The classification categories of each report are indicated at the start of each listing. These categories are:

1. WORK MEASUREMENT.
2. METHODS (also see 1).
3. PLANT ENGINEERING & DESIGN (also see 1 & 2).
4. HUMAN ENGINEERING (also see 1, 2 & 3).
5. ENGINEERING ECONOMICS (also see 3).
6. ORGANIZATION PLANNING (also see 3 & 4).
7. INDUSTRIAL STATISTICS (also see 1).
8. PRODUCTION CONTROL (also see 1, 3, 4, 5, 6 & 7).
9. DATA PROCESSING SYSTEMS DESIGN (also see 1 & 8).
10. OPERATIONS RESEARCH & SYSTEMS DESIGN (also see 3 & 8).
11. COSTS & COST CONTROL (also see 1, 3, 5 & 7).
12. INDUSTRIAL ENGINEERING EDUCATION (also see 6).

The Committee wishes to thank the organizations that have helped with this project, and to encourage the participation of all organizations in the extension of the project. Information should be sent to:

AIIE Research Information Committee
Department of Industrial Engineering
Washington University
St. Louis 5, Missouri

L. E. Davis — *Norman G. Myers*
C. R. Draper — *Leroy A. Wickstron*
David C. Ekey — *Jay Goldman, Co-Chairman*
C. B. Gambrell — *Gerald Nadler, Co-Chairman*

1. WORK MEASUREMENT

(Procedures Preparatory to Work Measurement, Timing, Measuring Operator Performance, Measuring Job Difficulty, Delay Allowance, Machine Control and Interference Allowances, Personal Allowance and Fatigue, Basic Motion Standard Data, Elemental Standard Data, Control of Standard Times, Special Labor Category Standard Times, Work Sampling).

1,2. Analysis of Effects of Weight, Distance, and Clearance on Basic Elemental Time; *Louis Charles Haefner, Jr.; 1956; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

The effects of positioning clearance, distance moved and weight moved on grasp, move and position, and release were investigated and the results reported. A randomized block statistical design was used and the data tested for significance by means of analysis of variance.

1. An Analysis of the Characteristics of Element-time Distributions; *Eugene Wesley Green; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The primary purpose of this research was to test the hypothesis that the element-time distribution characteristics do not vary significantly from the work-time distribution for the cycles of which these elements are a part. Secondary objectives were to investigate the relationship among elements in terms of their independency or dependency and to study the possible effects of the assignable causes of variation in work method on the distribution of element times. The results of this study indicated that, generally, the characteristics of the element-cycle distributions are similar.

1. Analysis of Work-time Distributions for a Short Cycle Manual Operation; *George H. Taft; 1954; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this work was to answer some of the questions concerning the effect of variables on the cycle time distribution. The individual operator modified cycle time distributions with variables included tend to be positively skewed.

1,2. The Combined Effects of Symmetry and Clearances on Position Plus Assembly Times for Mating Parts; *Edward Thomas Skoran; 1956; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A determination of what effects combinations of clearances and degrees of symmetry have upon position-plus-assembly times, and the degree of symmetry at which an object can be considered symmetrical.

1. A Comparative Analysis of Three Predetermined Motion-time Systems; *Mark Cicero Balkcom III; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

Within the limitations of the study, it was found that there was significant difference in the abilities of the three systems under consideration to measure the time for a given amount of manual work.

1,7. A Comparison of All-day Time Study vs. Work Sampling for Measuring Work in a Navy Supply Department; *Benedict Joseph Scott; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana. (Also see* **The Journal of Industrial Engineering,** *January-February, 1956).*

A comparison of the merits of all-day time study vs. work sampling as methods of measuring work for variable cycle operations and for indirect labor activity. Comparison was based on experience and the training of analysts necessary.

1. A Control Chart Analysis of Cycle Performance Times; *Robert Lawrence McLeod, Jr.; 1954; Library, Georgia Institute of Technology, Atlanta, Georgia.*

Evaluation of the significant changes appearing in the charts presented inconclusive evidence that the removal of the selected assignable causes of variation significantly affects the statistical stability of cycle performance times as studied.

1,11. Controlling Restaurant Labor Costs—Possible Applications; *Paul R. Broten; 1953; Librarian, Cornell University, Upson Hall, Ithaca, New York.*

A modification of recognized industrial engineering techniques for use in a specific inn and club. Basic differences between food service production and manufacturing are explored and criteria for determination of operating efficiency developed. The actual operation is described, the procedure developed in detail, actual data are presented and analyzed. For the small or medium operation, the applicability of routine time study techniques is questioned but use of certain ratio control is suggested as a profitable substitute.

1. Critical Analysis of Accuracy of Synthetic Motion Time Values as Developed by Motion Picture Analysis; *Robert A. Olsen; 1957; Industrial Engineering Department, Pennsylvania State University, University Park, Pennsylvania.*

Time values, determined with an electronic touch detector developed at Penn State were compared to values determined from motion pictures taken at a speed of 1000 frames per minute. The study indicated that move and reach values based on film analysis were too large and values for release based on film analysis were too small.

1. Critical Analysis of Predetermined Motion Time Systems; *Gerald Nadler; 1952; Proceedings of the Sixteenth Annual National Time and Motion Study and Management Clinic, Industrial Management Society, 35 W. Wacker Drive, Chicago 1, Illinois.*

Analysis of all systems, in existence or planned. Discussion of basic assumptions and the methods used for investigation of universal time values. The practical problems of application and the results of industrial application of the systems now in use. Procedures are given for accurate and consistent standards. Conclusions show that present predetermined motion time systems are a poor means for setting standards.

1,2. The Design and Evaluation of a Timer for Motion and Time Study Research; *Claus Baer Mettenheimer; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The first objective of this study was to investigate available timing devices and determine if any were suitable for motion and time-study research. The new timer reduced the initial cost of the device, substantially reduced the size compared to the Thuesen timer, and facilitated easier subtraction of times.

1. Design of a Modification of a Motion Picture Camera to Permit Stop Watch to be Photographed on Each Frame for Memo-motion Data Taking; *H. G. Thuesen; 1953; Oklahoma State University, Stillwater, Oklahoma.*

Design of a modification of a 16 mm motion picture camera to photograph a stop watch on each frame for memo-motion data taking on construction, oil field and similar activities at the rate of 10 to 300 frames per minute where 110 V. AC current is not available.

1. Design of a Timer to Print Record of Element Times (snap back times) to the Nearest .001 Minute and Identifying Element Symbols, Manual or Machine Actuated; *H. G. Thuesen; 1953; Oklahoma State University, Stillwater, Oklahoma.*

The timer will directly record elapsed times of work elements of .001 to 9.999 minutes duration to the nearest .001 minute on actuating a symbol identifying keys manually or mechanically.

1,2. The Development and Evaluation of an Automatic Photographic Ratio Delay Device; *Joseph A. Tolbert, Jr.; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The development and evaluation of a device to make an automatic photographic ratio-delay study is described, and a complete description of its construction and operation is given. This device consists of a predetermined sequence of random time intervals, an electronic timing circuit, and a sixteen-millimeter movie camera.

1,2,4. Development and Testing of an Electronic Method for Determining Acceleration, Constant Velocity, and Deceleration of Body Motions; *Jay Goldman; 1955; Engineering Library, Washington University, St. Louis 5, Missouri (Also see "Electronics for Measuring Human Motions,"* **Science Magazine,** *Vol. 124, No. 3226; "The UNOPAR,"* **The Journal of Industrial Engineering,** *January-February, 1958).*

An application of the Doppler effect for the electronic measurement of motions (velocity, acceleration, and displacement) in three planes. Development of the UNOPAR, (Universal Operator Performance Analyzer and Recorder).

1. The Effect of Job Difficulty Factors on Time, Energy and Acceleration of Motion Patterns; *Joseph Wray Wilkes; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

Four experiments were performed to determine and evaluate the relationships existing between operator motion, pace, and job difficulty factors. Conclusions: (1) Amounts of acceleration and deceleration are not identical in a motion. (2) Deceleration has a closer relationship to job difficulty than acceleration. (3) Motions are not independent in a sequence. (4) Two hand motions show reduction in performance from one hand patterns. (5) Increasing weight handled reduces performance. (6) Increasing positional eye-hand coordination requirements reduce performance. (7) Increasing directional eye-hand coordination requirements reduce performance. (8) Increasing level of muscular squeeze control reduces performance.

1. Effect of Operator Pace on Work Sampling Results; *Albert Burnell Drui; 1957; Engineering Library, Washington University, St. Louis 5, Missouri.*

Four jobs, each in a different industry, but having common traits, were selected for this experiment. The purpose of the study was to compare pace and work sampling as they are currently used in industry. The results indicate that the use of work sampling for the establishment of time study delay allowances would seem to be questionable if methods were not standardized as pace has a greater effect if this condition exists.

1,2. The Effects of Handling Conditions on Basic Motion Times; *William Richard Young; 1956; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The purpose was to study the effect of different conditions of manual handling upon the time to perform the basic motions involved in the work cycle. It was shown that the different conditions of handling involved had significant effects upon the times to perform the various therbligs.

1. Electronics in Work Measurement; *Gerald Nadler; 1955; Proceedings of the Sixth Annual Conference, American Institute*

of Industrial Engineers, 145 N. High St., Columbus 15, Ohio (Also see "Electronics in Work Measurement," **Time & Motion Study,** *Februar| 1957).*

Background and development of work measurement problems. Presentation of a new concept relating all time study components and measurements. A review of electrical and electronic techniques used in work measurement.

1. An Experimental Study and Statistical Analysis of Time Study Rating Ability of Operations on Film as Against Rating the Actual Operation; *J. Frederick Medford; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The primary purpose of this research was to investigate the difference between time study rating of actual operations and the rating of films of the operation to determine if there is a significant difference. By using two typical industrial operations an experiment was run with 21 experienced time study engineers rating first the actual operation and then films of the operations. Based on the results of the statistical analysis of the data of this research and within the experimental limitations the general conclusions reached were as follows: (1) There is some difference in rating of films as compared to rating of actual operations. However, there was insufficient evidence to say conclusively that this difference was significant. (2) Rating of film presentations is likely to result in a slightly higher average rating error than rating of the actual operation. (3) The differences between rating film and rating of the actual operation is likely to be related to the particular operations involved. (4) Individual raters are likely to perform differently in their rating of film as compared with actual operations. (5) The experimental subjects displayed a tendency to over-rate slow performances and to under-rate fast performances.

1,4. Eye-hand coordination as a Function of the Size of the Part and Tolerances; *John Christian Hug; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

Investigation to determine if time differences occur in performances as a result of changes in the size and tolerance of parts. Five cylinder sizes and five tolerances were used. Conclusions show that the time in general was affected by changes and therblig times were affected by interaction with other therbligs.

1. How Many Time Study Readings to Take? *Gerald Nadler; 1955;* **Factory Management & Maintenance,** *Vol. 113, No. 2, p. 132-3.*

A nomograph is presented as a representation of a statistical technique for determining the number of readings for a time study. Confidence limits are given for 1,2, and 3 sigma variation. The nomograph can also be used to spot trouble in the job under study.

1. The Incompatability of Predetermined Time System; *L. C. Pigage and I. L. Reis; 1954; Department of Mechanical Engineering, University of Illinois, Urbana, Illinois.*

A comparison of four predetermined time systems to show the inconsistencies of the systems, individually and collectively, and the lack of compatability of one system with another for selected basic motions.

1,2,4. An Investigation into Human Heart Rate Recovery as a Measure of Work Rate; *Leonard Joseph Deney; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The development of a standard task in which operators pace could be predetermined. This is followed by an accumulation of data and analysis of results. These results indicate a very high correlation between work pace and heart rate immediately following work.

1,2. An Investigation into the Effects of Clearance, Direction of Transport, and Location of Time Required for Position and Assembly of Mating Parts; *Wayne Stephenson Marshall; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Investigation of the effects of clearance on position and assembly times for mating parts. Investigation also of the effects of location of the work point relative to the operator and the angle of transport prior to positioning.

1. An Investigation of Four Methods Used in Stop-watch Time Study for Timing and Rating Work Activity; *Charles Thomas Johnston, Jr.; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The primary purpose of this research was to test the hypothesis that there is no significant difference in the consistency of four methods used in stop-watch time studies for timing and rating work activity. The secondary objective was to determine the sources of variation in the consistency of the four methods. Based on the results of the statistical analysis of the data of this research and within the limitation as stated, the general conclusions reached were as follows: (1) The results of this investigation do not indicate any significant difference in the consistency of the four methods in measuring normal time for manual, operator-controlled work activity. (2) Based upon the results of this experiment, selection and use of one of the four methods of timing and rating should depend to some extent upon the individual time study man.

1,2. An Investigation of Simultaneous Motions as Treated in the Methods-time-measurement System; *Edward V. Krick; 1952; Department of Industrial and Engineering Administration, Cornell University, Ithaca, New York.*

Presents an analysis of the present MTM method of synthesizing a bimanual motion pattern. A more realistic method is proposed and the data collected for the development of this new method are included. These data pertain to the visual direction requirements of various motions and to eye travel times.

1,4. An Investigation of the Causes of Error in Time Study Rating; *F. Stewart Clare; 1954; Engineering Library, Cornell University, Ithaca, New York.*

Describes the analysis of a large volume of ratings to investigate the effects of various traits and backgrounds upon rating error. Such variables as age, eyesight, weight, intelligence, past experience, etc., were tested for effect.

1,2. An Investigation of the Components of an Electronic Work Measurement Device; *Robert I. Hall; 1956; Engineering Library, Cornell University, Ithaca, New York.*

An analysis of error in electronic and electromechanical work measurement systems. Experiments to estimate the error of various components are described and the results reported. Concerns various sensing devices, relays, and electronic timers.

1,2. An Investigation of the Effect of Weight Lifted on Productivity; *Osman Fikri Sekerci; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A study of effect of weight lifting on productivity. A bar was used to which different weights were attached, and with a return mechanism to bring bar back to its original position after it was lifted. Conclusion that the number of lifts is linearly related to the weight, and decreases as the weight increases.

1,2. An Investigation of the Effects of Symmetry in Industrial Assembly Operations; *Malcolm Oliphant Scketky; 1955;*

Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.

A study of the effects of symmetry upon the time required for positioning and assembly of mating parts which had various degrees of symmetry. "Degrees of symmetry" was defined as the number of ways a part could be orientated about its axis while being assembled into a mating part.

1. An Investigation of the Independence of Time Study Elements; *Franklin Terry Perkins; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this investigation was to make an exploratory study of the relationship among the elements of a work cycle to determine if they were statistically independent. The basic data for two operators, one stable (statistically) and one unstable (statistically), were obtained from a micromotion study of a short cycle operation being performed in an industrial plant. It was found that there was evidence of correlation among the elements of the work cycle for both the five and two element breakdowns.

1,2. An Investigation of the Means by which a Worker Achieves a Change in Production Rate in Simple Operator-paced Assembly Work; *I. L. Reis; 1957; Library, University of Illinois, Urbana, Illinois.*

A microscopic study of motion paths of a simple operator-paced assembly showing how the inter-relationship of motion path and operator effect the variation in production rate.

1,2. An Investigation of the Pattern of Variation of Cycle Performance Times for a Repetitive Manual Operation; *Martin Hayes Kennedy; 1957; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this investigation was to study a worker's cycle performance times over a period of several days to determine if the cycle times of the worker exhibited any statistically predictable pattern. Linear trend lines, control charts, and various significance tests and comparisons were used to analyze the data. The results showed that there was generally no pattern of variation of an operator's cycle times with or without the time consumed by various assignable causes of variation intact. This study has shown that the concept of normality as applied to theoretical work-time frequency distributions may have some validity.

1,4. An Investigation of the Velocity Characteristics of Human Limb Motions; *Edward V. Krick; 1952; Engineering Library, Cornell University, Ithaca, New York.*

Describes the use of special stroboscopic photographs to estimate the effect of learning, degree of control, and pace, on the speed characteristics (acceleration and deceleration, maximum speed, etc.) of arm and hand motions.

1,9. Man-machine Interference I; *Billy Raines; 1954; Industrial Engineering Department, University of Arkansas, Fayetteville, Arkansas.*

Description of construction and function of simple machines utilizing sand and water flow to represent machine operating cycle times and service cycle times of a group of 2-6 semi-automatic machines; method of measuring interference during use of these machines. Construction details and operating instructions for electronic production computer which represents a group of 2-12 semi-automatic machines with variable ratios of operating time to service time; method of using production computer to calculate interference in actual industrial situations.

1,9. Man-machine Interference II; *Billy Raines; 1954; Industrial Engineering Department, University of Arkansas, Fayetteville, Arkansas.*

Further operating instructions for electronic production computer in greater detail; suggested maintenance procedures for computer, revised wiring diagram.

1,3. Management's Problem in Determining a Meaningful Measure of a Fair Day's Work in Connection with the Maintenance Work in Power Plants; *Eugene Bernard Meiners; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

To date no such measure has been developed, not because of its unimportance, but because of the sheer difficulty in developing such a measure. The results of this study show that the development of this measure is worthy of serious consideration by management, and that management problems in determining this measure are capable of being solved.

1,4. Measures of Pilot Tolerance to a High Thermal-noise Environment; *Edwin G. Aiken and R. C. Armstrong; 1957; Convair-San Diego, A Division of General Dynamics Corp., Engineering Dept., Human Factors Engineering Group, San Diego, California.*

An experiment was conducted which tested the effect on certain physiological and performance measures of a high thermal-noise cabin environment characteristic of future high performance aircraft. A condition considerably more severe than in existing vehicles was found tolerable by all measures.

1. Predetermined Time Standards for Variable Set-ups; *D. Drewery and R. Coats; 1955; Industrial Engineering Department, Harnischfeger Corporation, 4400 West National Avenue, Milwaukee, Wisconsin. (Also see* **The Journal of Industrial Engineering,** *November-December, 1957).*

This paper is a step by step explanation of the development of a system of predetermined work measurement as applied to setting up machine tools where the work method cannot be known in advance. The paper cites actual examples as well as a summary of the results of its application to several types machining centers.

1. Predicting Success in Time Study; *Hayne deYampert McCondichie; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this thesis is to determine, exactly what traits characterize the successful time-study man, and to determine if success in this field can be predicted on the basis of certain aptitude tests which purport to measure these necessary traits. The results indicated that intelligence is the one trait most essential for success in time-study work, and that ability in structural visualization is helpful.

1,2,7. A Ratio Delay Study of Long Cycle Operations Performed by a Variable Labor Force; *William Judd Halladay, Jr.; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia. (Also see* **The Journal of Industrial Engineering,** *July-August, 1956).*

The purpose of this experiment was to test the hypothesis that Ratio Delay will give valid, unbiased estimates of activity percentages when used to measure operations involving a variable labor force performing long cycle operations, and to determine the effective sample size with which the reliability of the Ratio Delay percentage estimates can be assessed. The results of the experiment indicate that Ratio Delay will give valid, unbiased estimates of activity percentages when used to measure a variable labor force performing long cycle operations.

1,2,4. The Relationship Between Heart Rate and the Intensity of Work for Selected Tasks; *Haidar Amin Tarabashi; 1956; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Investigation of the relationship between heart rate immediately following a timed interval of work and the intensity and/or pace of work for certain selected tasks. Each task was performed for a period of two minutes, followed by a ten minute rest period. *(Also see* **The Journal of Industrial Engineering,** *November-December, 1956).*

1,2. The Relationship between Job Standardization and Operator Production; *Robert Donald Kelly; 1955, Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Purpose was to test the hypothesis that the performance of operators on a standard method of doing a production line assembly task would be superior to their performance on alternative methods of performing the same task. Results show that performance of operators on standard method was superior or equal to their performance on alternative methods.

1. The Relationship between Stability of Cycle Performance Times and the Characteristics of the Work-time Distribution; *Frank Andrew Summers; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this study was to determine if any relationships exist between cycle time stability and the characteristics of the work-time distribution.

1,2. The Relationship between Work Tempo and Force Applied in a Horizontal Plane; *Donald Edward Gately; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The apparatus used was a table with a handle protruding through a slot in the top surface. A mechanism made it possible to increase and decrease the resistance to movement in one direction. Results show that work tempo and force applied horizontally may be considered to be linearly related.

1. Standard Data Problems and Solutions; *Paper No. 53-F-16; Gerald Nadler; 1953; The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y.*

Work measurement is greatly simplified if time studies are converted to elemental standard data. If time study procedure used is such that the errors are minimized, standard data offers an economical means of determining work loads. Statistical tools are presented to point out how the following problems are solved: (1) Are the variations of base times within satisfactory limits? (2) Is there a factor present affecting the times, and if so, what is the factor? (3) Is the curve drawn the proper one?

1. A Statistical Analysis of Some of the Causes of Timed Variance in Stop Watch Time Study; *George Forrester; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The objective of this study was to evaluate the effect, if any, of the length of an element and its complexity on the timed variance. There was no evidence of a relationship existing between the timed variance and the length of the element, but the correlation between the timed variance and the element complexity was, statistically, highly significant.

1,2. A Statistical Analysis of Work-time Distributions; *Warren Ellsworth Lind; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

This study considered some of the questions that must be answered before a formal mathematical model can be determined for performance times. Several characteristics of this model were studied. One of several conclusions was: The unadjusted performance times tend to form a positively skewed distribution.

1. A Statistical Investigation of the Stability of Industrial Cycle Times and the Correlation of Variability and Central Tendency of Cycle Times. *James M. Moore; 1956; Engineering Library, Cornell University, Ithaca, New York.*

Describes the collection and analysis of a large volume of cycle time data on several industrial operations, and the results. The analysis concerns stability, nature of the distribution, correlation between sample mean and sample variance, and logarithmic transformation.

1. Statistical Procedures in Standards Auditing; *I. Landis Haines and Paul E. Green; 1957; Lukens Steel Company, Strode Avenue, Coatesville, Pennsylvania. (Also see* **The Journal of Industrial Engineering,** *September-October, 1957).*

This report contains two statistical techniques, both of which may be used for auditing production time standards. The purpose of these techniques is to reduce the time necessary in determining the accuracy of existing standards within certain predetermined limits.

1. Studies in the Relationships of Therbligs; *Gerald Nadler and J. Wray Wilkes; 1953; Engineering Library, Washington University, St. Louis 5, Missouri. (Also see* **Advanced Management.** *February, 1953).*

The purpose of this research was to learn what would happen to the times for each of the individual therbligs in a job as the mechanical procedure for one therblig was changed. The procedure involved the manipulation of dials and switches by six different operators. Conclusions show that the attempts at determining a universal time value for individual therbligs as done by pre-determined motion time systems do not seem to be warranted.

1,2. A Study of Element Interdependence; *Klaus Prikel; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The project was undertaken to investigate the statistical characteristics of performance-time variations for a short cycle manually controlled operation. This work investigates the occurrence of minor methods variations and their influence on the performance-time patterns previously studied. Results of this investigation indicate that the occurrence of minor methods variations in the job studied cause instability, as measured by control charts and analysis of variance. There is some evidence that the occurrence of minor methods variations is accompanied by a "speed-up" in the performance of work elements following the occurrence of minor methods variations, but this "speed-up" is not confined to any specific elements following the occurrence of the variation in method.

1. A Study of Experimental Work-time Distribution Characteristics to Determine the Existence of a Typical Distribution; *Paul Harold Friedman; 1954; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The objective of this work was to study the characteristics of experimental work-time frequency distributions and to determine the existence of a typical distribution for statistically stable operators on a short, manually controlled repetitive operation. In view of the experimental situation, it seems reasonable to conclude that there is a theoretical work-time distribution which typifies work-time phenomena for this type of activity.

1,2. A Study of Move and Reach and the Effect of Hand in Motion; *Clifton A. Anderson; 1957; Industrial Engineering Department, The Pennsylvania State University, University Park, Pennsylvania.*

This pilot study disclosed that a statistically significant greater time is required to perform the combination move and reach than is required for a move of the same distance. This finding is

in contrast with present practice. The results are based on limited data and are subject to verification by a controlled experiment involving more data on the most important factors.

1,2. A Study of the Effect of Entry-clearance on the Times Required for the Motion Elements Comprising Position; *John S. Kernachan; 1957; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

The effect of variation in entry clearance on the time required for move, position, and the align part of position was investigated and results reported.

1,4. A Study of the Effects of Motivation on the Work-time Distribution of an Operator on a Repetitive Manual Operation; *William Henry Muse; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The study attempts to determine if the characteristics of the work-time distribution of an operator on a repetitive, manually-controlled operation are affected by changes in the degree of motivation of the operator. The approach in this study was to observe one operator on one standardized, repetitive, manually-controlled operation. The following conclusions were made as a result of this study within the limitation set forth: There was no significant linear correlation between the mean and the skewness, between the mean and the standard deviation, or between the mean and the peakedness of the work-time distributions of the operator on this operation. The operator's performance-times tended to be unstable on this operation due to changes in pace of the operator as well as to assignable causes of variation which were not visually detectable. The work-time distributions for the operator on this operation were positively skewed. The work-time distributions for the operator on this operation were more peaked than the normal distribution.

1. A Study of the Effects of Practice and Changes in Effort on the Performance Time of the Different Motions in an Industrial Manual Operation; *Horacio A. Brea; 1955; Engineering Library, Cornell University, Ithaca, New York.*

Primarily, this is a description of an investigation of the hypothesis that changes in effort effect a much greater change in time for performing travel motions than for performing manipulative motions. The report describes studies made on factory operations, a statistical analysis of the data collected, and the implications of the findings.

1. A Study of the Influence of Level-of-performance on Work-time Distributions; *Herbert Stephen Wilson; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this study was to evaluate the influence of pace or level-of-performance on operators' distribution of work-times in an industrial work situation. The objective of the investigation was to determine whether or not the removal of the influence of pace would significantly affect the moments or the curve fitting capabilities of the distributions of work times. The combined distributions evidenced no significant tendency to have their moments altered as a result of the leveling process.

1. A Study of the Inter-relationship of Therblig Times; *Kenneth Williams Heising; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The testing of the hypothesis that time values for certain therbligs cannot be given as universal values since they are influenced by other therbligs in the sequence. The experiment was given a thorough statistical analysis of variance.

1,2. A Study of the Time Effects of Certain Compound Motion Impedances on Manual Transport Times; *Stewart Warren Timmerman; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The time synthesis procedure for movements entailing two or more impedances, is quite controversial. The controversy is over the question of whether the time effects of two or more impedances occurring together is equal to the sum of the individual impedance times when the impedances occur separately. The object of this research was to determine, for typical conditions, the answer to this question. The results of this research indicate that, for the typical impedances tested, the sum of the individual (the synthesized) normal slow-down times for impedances comprising a compound impedance is significantly greater than the normal slow-down time produced by the compound impedance.

1,2. A Study of the Time Effects of Distance, Direction, and Simultaneity on Manual Transport Motions; *Harrison Maclon Wadsworth, Jr.; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

This research was intended to fulfill three specific needs for the refinement of synthetic motion and time study. These needs are: first, the development of an experimental procedure which can be duplicated by others; second, through use of this experimental procedure, the establishment of the estimated normal movement times for fundamental transport empty motions, of varying distances, made while seated; and third, the measurement of the comparative time effects on different body members making like movements of like distances. Percentage difference in the normal time of twelve-inch motions, the key task, compared with longer motions are shown by means of curves.

1,2. A Study of Work Performance Phenomena, *Cecil Gray Johnson; 1957; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The formulation of a theoretical mathematical model to describe the characteristics of work performance phenomena was the objective of this investigation. The results reject the null hypothesis that the characteristics of the work performance curve follow the normal distribution curve. A primary recommendation for continuing this work centers around the hypothesis that the variations in a worker's performance conform to the compounded effects of the basic laws of motion plus a constant chance cause system.

1. A Study of Work-time Distribution Characteristics and Their Relationship to Delay Time Distribution Characteristics for Several Operators During Similar Work Periods; *Nelson Kimball Rogers; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this study was two-fold. Studies of work time frequency distributions derived from sample sizes larger than five hundred were obtained in order to determine the general nature of the parameters of such distributions and the results were then compared with previous research in this area of work measurement. Delay time distributions were obtained in order to determine the general nature of their parameters and these results were studied to find out if they had any relationship to the work-time distributions obtained during similar observation period for the initial operator observed. Work-time distribution means for individual operators varied significantly from hour to hour in the observation period, but the standard deviation of the individual operators did not show significant variation.

1,8. A Survey of Elements Controlling Ground Time in Airline Operation at Indiana Airports; *Douglas F. Corsette; 1952; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Purpose was to collect sufficient data from the elements of air-

plane ground time to facilitate a determination of the amount of statistical "control" with respect to these elements. A proposal of standard times for such elements as might display sufficient stability to be reliable.

1. Theoretical Considerations in the Rating of Time Studies and the Development of Standard Time Data; *Joseph V. McKenna; 1951; Engineering Library, Cornell University, Ithaca, New York.*

A description and analysis of time study methodology, with emphasis on rating and the predetermined motion time technique.

1. Therblig Relationships: I. Added Cycle Work and Context Therblig Effects; *Gerald Nadler and Donald H. Denholm; 1955, Engineering Library, Washington University, St. Louis 5, Missouri. (Also see* **The Journal of Industrial Engineering,** *March-April, 1955).*

A series of experiments to determine the effect on the cycle time, when adding an element of work to the established cycle therblig times, and the motion path of the original cycle. Conclusions: (1) An element of work introduced in the original cycle significantly affects the original total cycle time and the length of the hand movement. (2) A change of work conditions of one therblig significantly affects the total cycle time.

1. Time Study Rating Evaluation; *Gerald Nadler;* **The Journal of Industrial Engineering,** *November, 1953.*

Statistical methods to increase consistency of operator performance rating. Suggestions for the training of observers, as well as group and individual rating analysis techniques.

1,4. Work in Hot Places (5 parts); *Professor Dr. Bruner, Dr. H. Hornicke; 1951-1953; Dr. Heiko Hornicke, Physiologisches Institut der Tierärztlichen Hochschule, Hans-Bockler-Allee 16, Hannover, Germany.*

Report on heart rates blood pressures and rectal temperatures of miners in coal and potash mines, measured under different working conditions. Correlation of the physiological data with the simultaneous measured components of climate. Valuation of different indexes of climate.

2. METHODS. *(Non-repetitive Work Analysis Technique, Repetitive Work Analysis Techniques, Basic Principles Investigation, Evaluation Procedures, Testing Procedures, Installation Procedures).* Also see 1.

2,3. Certain Concepts of Operations Design; *Joseph William Gavett; 1956; Engineering Library, Cornell University, Ithaca, New York.*

A study of the design function as it pertains to design of industrial operation; related functions; the system and its elements; the general characteristics of the design function in terms of its futurity, progressive stage, restrictions of various types; the methodology of design, analysis, synthesis, creative methods; the organization of design function.

2,3. Descriptive Variables for the Study of Task-oriented Groups; *Robert Glaser; 1956; Tenth Annual Conference on Current Trends in Psychology, Measurement Laboratory and University Testing Service, University of Pittsburgh, Pittsburgh 13, Pennsylvania. (Also published in Contract N7 ONR 37008, NR-154-079, Office of Naval Psychological Research, Sciences Division, Personnel and Training Branch.)*

This report presents a series of measurable variables for the description and analysis of a complex of men and machines. Thirteen variables are described which consider information flow, time sequence variables, and process variables.

2,3. Design of a University Packaging Laboratory; *Kenneth D. Brunelli; 1957; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A thorough literature survey is presented on some of the present methods and procedures for testing packaging materials and containers. A visit survey was performed in existing laboratories. A proposed packaging laboratory is presented.

2,4. A Determination of the Effect of Lever Length Upon Cycle Time; *Robert Edward Peale; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Equipment was built to apply a desired torque to a shaft which is rotated between mechanical stops by the operator. Results show that cycle time decreases as lever length is decreased to an optimum point.

2. The Development of a Methodology for the Evaluation of Patient Care; *D. Howland (Project Supervisor); 1956; Operations Research Group, Ohio State University, Columbus, Ohio.*

The purpose of this project is the development of a methodology for the evaluation of patient care by hospital planners and managers in their own hospitals. A general model of the hospital system is being developed which will relate the utilization of the resources of physical plant, staff, patients to the consequences of their utilization for patient care.

2,3,4. The Effect of Switch Handle Shapes on Time Required for Operation at Various Heights; *Elmo Gaylord Lindquist; 1952; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Determination of whether the use of several common shapes of handles, for a generally used type of switch, would result in a minimum amount of time required to operate the switch at various heights. Data shows circular switches to be better than rectangular.

2,3,4. Effect of the Number of Rows of Objects and the Width of the Visual Field on Visual Inspection; *Clarence Chandler Gerrard; 1955; Library University of California, Berkeley 4, California.*

It was found that there was a visual limitation on inspection efficiency in that the total effective width of the visual field at the conveyor belt is approximately eleven inches.

2,3. Elevator Passenger Transfer Time Study; *John William Persohn; 1957; Library, Oklahoma State University, Stillwater, Oklahoma.*

Development of a system of data taking for determining passenger elevator needs.

2,4. Integrated Instrument Development; *ES Report No. 26040; 1955 Douglas Aircraft Company, 827 Lapham, El Segundo, California.*

The objective of the proposed development program is to study the requirements of an adequate flight information presentation and the feasibility of integrating the information and control systems to present adequate information to the pilot and at the same time supervise as many of the control functions as possible.

2,3. An Investigation into the Operation of Fork Lift Trucks; *John Anthony Crosse; 1952; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An analysis of the operation of fork lift trucks using the principles of Micromotion study. The elements determined were: pick up, maneuver loaded, transport loaded, release, maneuver empty, transport empty. Controlling variables were determined.

2. An Investigation of Methods and Positions Used in Manual Quality Picking of Small Objects; *Peter Wright; 1957; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this study was to determine the optimum picking method and picking position which should be used in the manual quality picking of small objects. The objects used were Great Northern beans containing 4 percent (by weight) Pinto beans which represented the defective objects. A factorial mixed model experiment was employed to test the effect of certain independent variables upon the operator's performance.

2,4. An Investigation of Modifications of Job Design in an Industrial Situation and their Effects on Some Measures of Economic Productivity; *Arthur Richard Marks; 1954; Library, University of California, Berkeley 4, California.*

A job-centered approach has been proposed to measure effectiveness of job design in terms of direct and indirect costs leading to economic productivity. It was found that the addition of responsibility to an assembly process having repetitive operations and a minimum of responsibility can result in improved quality of product, without loss of production, and more favorable worker attitude.

2,3. An Investigation of Some Factors Affecting the Hand Quality Picking of Small Objects; *William W. Calhoun, 1955; Library, Georgia Institute of Technology, Georgia, Atlanta.*

The purpose of this thesis was to investigate the effects of the following independent variables on the picking rate and the quality of the pickouts in the operation of hand quality picking: operator, method, position, belt speed, damage-density, belt loading, replications. The following conclusions were reached: (1) Operators demonstrated statistically significant differences in both picking rate and quality of picking. (2) The use of a low belt loading with the operator stationed at the side of the picking table, and using a method in which the defective objects are tossed aside as they are grasped, produced a higher picking rate and fewer good objects in the pickouts.

2. An Investigation of the Effect of Minute Path Variations upon Operator Performance; *Robert Ora Clark; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Comparison of minute variations in motion paths, for standardized therblig activity, with the times required to complete these motions as a measure of operator performance. Statistical analyses of the results showed that a significant difference exists in the motion paths used at standardized performance levels.

2,4. Pilot's Eye and Control Wheel Position; *J. A. Roebuck; 1954; Douglas Aircraft Company, Inc., 3000 Ocean Park Boulevard, Santa Monica, California.*

A total of 49 persons were measured in a special mockup seat to determine the natural position of their eyes and the farthest aft position they preferred to pull a control wheel while turning it. Four other pertinent body dimensions were also measured to compare the sample group tested to the sample representing anticipated operating personnel, and to study relations between dimensions.

2,3,4. The Relationship Between Visual Inspection Efficiency and the Vertical Field of Vision; *Bernard Lawrence Keating; 1956; Library, University of California, Berkeley 4, California.*

Purpose to investigate effect of different magnitudes of the vertical field of vision upon ability of operators to visually inspect objects in a conveyor belt type inspection operation. It was found that the size of vertical field was not an important limitation, however, rate of flow of test objects was a critical limitation. A single row of objects was found to be better than two rows, one above the other.

2,4. A Study of Habit Facilitation and Interference in Learning Assembly Operations; *Robert Bernard O'Connor; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this research were to evaluate the effects of similarity of operation elements, and the effects of level of learning on one operation before learning on another operation is begun. The conclusions reached were that there was strong evidence to suggest that the individual motions involved in learning an element of an operation act as a set of stimuli and response, and the greater the similarity of the sequence of motions involved in two or more sequences of motions, the greater will be the interference between them, and that positive transfer may be present also, in which case the two effects cancel each other.

2. A Study of Job Design Criteria; *John Howell Hoffman; 1953; Library, University of California, Berkeley 4, California.*

Examination of practice in 27 companies to determine whether jobs are designed by worker preference, plant layout, or equalization and development of work load. Alteration of job content was not considered to remedy low productivity, poor quality or high employee turnover.

2,3,4. A Study of the Effect of the Diameter of Hand Wheels on the Time Required for Adjustment; *Carl Mathew Kromp; 1952; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Answer to the question arising concerning the speed with which operators can manipulate handwheels of various sizes to a desired degree of accuracy under various load conditions. The smallest diameter handwheel gave slowest operator performance for torques studied, while largest diameter wheel was the optimum.

2,4. A Study to Develop Simplified Procedures for Evaluating the Human Physical Factors in a Work System; *John Stewart Hunsinger; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this thesis was to develop a simplified procedure for evaluating the human physical factors in a work system. The judges ranked the subjects by the paired comparison and factor method of evaluation and these two ranks formed the dependent variables. Multiple correlation formulas were derived for the independent variables and each of the dependent variables. The important factors, whether they be physical or mental skills, can be measured using appropriate tests.

2,3,4. Visual Inspection and Concurrent Reinspection of Spheroids in Combined Translation and Rotation; *Keith Clark McKinney; 1955; Library, University of California, Berkeley 4, California.*

The purpose of this study was to analyze effects of operating conditions and workplace designs on the results of visual inspection of spheroids and to establish estimating equations so these effects are predictable. A parallel purpose was to present a testing design using incomplete blocks. Test results were analyzed and combined into 8 equations which permitted prediction of the combined effect of the variables.

3. PLANT ENGINEERING AND DESIGN. *(Plant Layout Analysis Techniques, Plant Layout Basic Principles, Plant Layout Evaluation Procedures, Plant Layout Testing Procedures, Plant Layout Presentation Procedures, Materials Handling Analysis Techniques, Materials Handling Basic Principles, Materials Handling Selection and Evaluation Procedures, Materials Handling Testing Procedures, Materials Handling Equipment Design,*

Maintenance, Plant Location, Plant Design and Construction, Tool Engineering, Safety, Mechanization, Inspection, Packaging). Also see 1 & 2.

3. An Analysis and Evaluation of Industrial Maintenance Spare Parts Storesrooms and their Relationship to Inventory Control; *George Wendell Morris; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of the study was to investigate and evaluate methods of operating maintenance spare parts inventories and storesrooms. The method of investigation was a personal interview with the executive in charge of the maintenance spare parts storesroom in fifteen representative industrial and utility establishments in Atlanta, Georgia. This was supplemented by literature search and by correspondence with persons having extensive experience in the field.

3. An Analysis of Some Machine Tool Replacement Formulas; *James Bernard Shaffer; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

This thesis determines the differences in the methods used and the factors considered by the various formulas in solving a replacement problem. The effects of errors in estimating the results given by a particular formula were determined.

3.8. The Application of Graphics in Planning Automation; *Richard Claire Carpenter; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The determination of the basic steps that must be considered in planning an automatic process. A consideration of the graphical aids that can be used in these planning stages. Various steps for the process are discussed.

3,8. The Application of Industrial Engineering Methodology to the Determination of the Requirements for a Model Livestock Auction Market; *Aaron Glickstein; 1956; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Four aspects of a livestock auction market are considered. These are the criteria for: the location of a livestock auction market, sales plant facilities, dock facilities and auctioning procedures. Time studies were made of auctioning procedures to examine relationships between lot size and auction time.

3,10. Balancing of a Continuous Production Line; *Benjamin Bryton; 1954; Northwestern University, Technological Institute, Evanston, Illinois.*

The model of line balancing presented here is an outgrowth of studies in economics, industrial engineering, and mathematics. It is an application of a philosophy found in these sciences which today is referred to as "Operations Research." This philosophy encompasses concepts of model formulations and their optimizations. The purpose of this study is to investigate a method for balancing a continuous production line; in other words, to determine the arrangement of work elements that minimizes unproductive station time assuming the method to be fixed, the inventories a minimum, and the product invariant.

3. A Comparative Analysis of Visual Layout Techniques as Applied to a Medium Size Job Machine Shop; *Earl Israel Denenberg; 1954; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this work was to determine which of several layout techniques would best satisfy the requirements of a typical job shop layout or re-layout. The conclusions obtained did not specify any one particular technique for universal application to job shop operations. Instead, it was determined that the model technique was the best choice where time limitation was the governing factor, while the templet technique was preferred where capital investment had to be minimized. Where time limitation and the capital expenditures are of approximately equal importance, the statistical analysis designates the model technique as preferable.

3,5,6. Considerations in Automating a Medium-size Metal-manufacturing Plant; *Charles A. Wanner; 1956; Engineering Library, Washington University, St. Louis 5, Missouri.*

This paper presents: (1) a brief survey of increasing automaticity, (2) a proposed procedure for introducing automation, and (3) associated problem areas. No effort has been made to discuss in detail any of the multitude of mechanical and electronic devices which are the physical solution of automation problems.

3. Conveyor-belt Tests for Harvesting Cannery Tomatoes; *L. E. Davis, C. Lorenzen, J. MacGillivray, L. J. Clemente, F. Zink; 1953; Department of Vegetable Crops, University of California, Davis, California.*

A new type conveyor-belt harvesting device was designed, tested and evaluated for use in harvesting cannery tomatoes.

3. Dental Bur Research at Northwestern University Dental School and Technological Institute ("Mechanics of Cutting with Rotary Dental Instruments") *E. W. Skinner, R. L. Lasater, R. S. Lindenmeyer; 1952-57; Northwestern University, Technological Institute, Evanston, Illinois.*

The equipment used in this research for obtaining cutting speeds, observing the cutters and measuring the bur variables is reviewed. The subject of efficiency of dental cutting is reviewed in detail, examining the theoretical considerations involved and using them for the design of experiments to determine such efficiencies.

3. A Design for Non-sticking Plug and Ring Gages and Locators; *Lawrence E. Doyle, Bernard R. Better, and Bei Tse Chao; 1956; University of Illinois, Engineering Experiment Station, Urbana, Illinois.*

The basic causes of sticking are evaluated. On the basis of the evaluation, formulas are given for the proper design of common types of plugs and rings used for gages, fixtures, jigs and other tools.

3. Development of Procedure for Fork Lift Truck Selection; *Alfred S. King; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Development of a more logical and usable procedure for selection of fork lift trucks as to make and model. A survey was made of the fork lift truck manufacturers' representatives. Conclusion was reached that many users depend upon hit-or-miss selection techniques.

3. The Effect of Die Clearance on 1020 Steel under Dynamic Loads; *Walter E. Thomas; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A determination of the minimum work required to blank a ½ inch diameter slug using various thicknesses of prime quality SAE 1020 steel by means of electronic pickup equipment.

3. An Evaluation of Various Measuring Sticks as a Basis for Predicting and Controlling Maintenance in a Chemical Plant; *Raymond John Stratmeyer; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

The characteristics that a measuring stick must possess are determined, and then possible measuring sticks are evaluated to ascertain if they possess these characteristics. Kilowatt-hours alone possessed the necessary characteristics for most applications.

3,8. An Experimental Investigation in the Field of Dynamic Stripping Forces in Punching Operations; *Hans Coster; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A stripping force is that force necessary to withdraw a punch from a punched hole. The purpose of this thesis is to design and build a test set-up based upon electronic methods to attempt this force. To determine the usefulness and the rehability of this apparatus.

3. An Experimental Investigation in the Field of Dynamic Stripping Forces in the Punching of Titanium; *Ferreira, Sergio de Freitas Carpenter; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A study of the effect of both punch die clearance and orientation of surface grain lay of the punch in the stripping forces of uranium. The design of a stripper plate that would lend itself to the measurement of the stripping forces involved.

3. How to Analyze your Materials Handling Problems; *Gerald Nadler and Jay Goldman; 1954;* **Mill & Factory.**

A new charting and analysis technique is presented as an approach to the systematic solution of M-H problems, considering these factors: (1) kind of material to be moved. (2) amount to be moved. (3) from where is the material moved. (4) to where is it moved. (5) how is the material handled. (6) what is the distance moved. The charting technique permits the application of both motion and time study and materials handling principles for improvement and design of produce processes.

3,4,5,11. Some Initial Policy Considerations in the Installment of Automation; *Robert Howard Bock; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The purpose of this thesis is to codify a management definition of automation, isolate various management problems concerning automation, and suggest a short term factory policy to combat operational problems.

3,8,10. Investigation of a Motor Freight Firm; *D. Howland (Project Supervisor); Mr. J. Ralph Riley, President, Suburban Motor Freight, King Avenue, Columbus, Ohio.*

This project, initiated in 1955, has been concerned with the various aspects of maintenance and scheduling of a motor freight firm. Emphasis has been placed on the development of failure theory for complex equipment and for the development of an over-all model of the Surburban Motor Freight System.

3,8. An Investigation of an Improved Method of Drying Hand Cores; *Robert J. Wimmert; 1952; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Investigation of the induced flow process for drying hand cores. A special experimental oven was constructed. Cores from this oven were compared with cores from conventional ones with favorable results.

3,4. An Investigation of Belt Speeds and Densities Used in Manual Quality Picking of Small Objects; *Carlos Olivares; 1957; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The aim of this thesis was to provide a more refined basis for the selection of optimum conditions to be used in the manual quality picking of small objects. In specific terms, the following is the objective of this thesis: to determine if there are belt speeds common to the three rates of flow of objects at which optimum picking rates, and high quality of pickouts, result. A factorial mixed model experiment was employed to test the effect of certain independent variables upon the operators' performance.

3. Investigation of Carbide Milling Grades 302, 303, and 303X Stainless Steels; *Kenneth Eugene Botkin; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Experiment undertaken to compare tool angles, surface finish, power consumption, and tool life for the three grades of steel. Tests were made with two grades of carbide tipped tools on two inch stock using .160 inch depth of cut.

3. An Investigation of Cutting Speeds for Economical Production in Metal Cutting Industries; *Max Grobly; 1953; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this study was to investigate cutting speeds in order to determine the most economical production possible in metal cutting industry.

3. An Investigation of the Amplitude and Frequency of Vibrations in the Standard Milling Machine; *Clyde Preston Smith; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A discussion in detail of several tests which were run in an attempt to analyze the vibrations present in the standard milling arbor. Investigation was also made to determine the effect of placing damping rings on each side of the cutter.

3. An Investigation of the Automation Potential in Several Georgia Industries; *Charles Louis Hohenstein, Jr.; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

This study is an attempt to evaluate the automation potential of several Georgia firms and to generalize principles relating to automation. A potential to use automatic techniques was observed to exist in greater or lesser degrees of all the processes analyzed. However, no economic evaluation of the proposed installations were made. Of the various ratios computed, Equipment Investment to Number of Production Personnel was the best indicator of relative process automaticity.

3. An Investigation of the Behavior of a Typical Epoxy Punch Used in a Sheet Metal Drawing Operation; *Fred George Haubold; 1957; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A quantitative analysis of the behavior of an epoxy material under a moderate production set-up. The analysis included observation of abrasion resistance, surface hardness, and dimensional stability.

3,8. An Investigation of the Principles of Design and Application of Automatic Feeding Equipment for Machine Tools and Presses; *David Eugene Fyffe; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Organization and consolidation of some of the available information concerning the design and application of automatic feeding equipment and of recognizing some of the guiding principles involved. The thesis is offered as a guide in the selection of such equipment.

3. An Investigation of the Relative Abrasion Resistance of Filled Epoxy Plastics; *Leon Herman Miller, Jr.; 1957; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A determination of what effect different fillers and filler concentrations would have on the abrasion resistance of filled epoxy plastics. The five different fillers were: Iron filings, iron oxide, alumina, copper and graphite.

3. An Investigation to Determine the Optimum Cutting Conditions for Maching Joslyn Stainless Steel, Series 302, 303,

303X; *Mohamed Ibrahim Dessooky; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Machinability of the three grades of steel was evaluated by tool life, surface finish, and power consumption. Tests were made with carbide tools having seven different shapes. Two grades of high speed steel, clarite and molite, were used for another group of tests.

3. Materials Handling in the General Warehouse; *W. Grant Ireson and Fred D. Stone; 1957; Department of Industrial Engineering, Stanford University, Stanford, California.*

These reports deal with the economic analysis of materials handling systems, an audit of the utilization of space in a general warehouse, a bibliography of warehouse handling articles, and a graphical method of determining the optimum pattern for stacking cartons of any size on a pallet of any size.

3. Methods and Attachments for Improving the Efficiency of Small Lot Production; *Ali Asghar; 1953; Librarian, Cornell University, Upson Hall, Ithaca, New York.*

A discussion of attachments for general purpose tools including lathes, milling machines, drill press. Included are check lists of questions to aid in selection of attachments.

3. Plant Site Survey; *Chester L. Brisley; 1954; Kresge Science Library, Wayne State University, 5450 Second Avenue, Detroit, Michigan.*

This thesis formulates the underlying principles of the location of a new plant. It is a pioneering project using a scientific approach in locating a plant site as developed by the author in making a survey for a company employing his services. It shows the approach made to analyzing 188 communities and reducing this number to one. It is hoped that as a result of this survey, this thesis might be a stimulation to further inquiry in the field.

3. Pressure Relieving Capacities of Lead Rupture Discs; *Louis Walter Sprandel; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

Development of an equation for estimating the bursting pressure of discs ranging in size from 0.011 to 0.0655 inches thick and having diameters from 1.16 to 13.2 inches with temperature and unit stress constant. The equation will account for 96.28% of the variation in estimation of the bursting pressure.

3,5,6. Primary Decision Factors Regarding Automation in a Discrete Products Industry; *Joseph Donald Zelanzy; 1956; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

To gain a thorough knowledge of what automation is by briefly studying the historical development, the definition of the work, the effects of automation upon managements, some of the more important responsibilities of management with regard to automation, and primary factors to be considered in making decisions about automation.

3. A Quantitative Approach to Equipment Location in Intermittent Manufacturing; *Robert J. Wimmert; 1957; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana. (Also see* **The Journal of Industrial Engineering,** *July-August, 1958).*

The first portion is a review and critical evaluation of criteria for plant layout proposed by the contemporary plant layout authorities. The second portion considers the traditional operations research techniques which might be applicable. A summary problem is included.

3. Selection of Materials Handling Equipment Under Varying Factors; *Allan Owen Holtzman; 1955; Engineering Library, Washington University, St. Louis 5, Missouri (Also see* **Mill & Factory,** *Vol. 58, No. 6).*

A review of all types of Material Handling equipment normally used within a manufacturing plant and its adjacent industrial facilities. A graphical selection device is offered for relating factors affecting handling situations with types of equipment.

3. Statistical Techniques for Classifying Foundry Sands; *John Milton Leaman; 1955; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

The objectives of an "Ideal" classification system for foundry sands are set forth and a system developed utilizing three statistical parameters which approximate the ideal.

3,5. A Study of the Effect of Increasing Levels of Mechanization Upon Manufacturing Cost at Selected Production Rates; *Philip Shewwood Mentz; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Systematic determination of the points in an ascending production rate at which it is economically desirable to modify the processing method. The problem is not only one of total process change, but of the degree of change as well.

3. A Study of the Flow of Bulk Material in Bins; *John Warren Reese, Jr.; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Flow stoppage is defined as the hanging-up of materials within a bin. This report studies the background material to try to define the factors contributing to flow stoppage in a bin. A particular factor is isolated to determine experimentally its contribution to flow stoppage.

3. A Study of Tool Chip Interface Temperatures and Cutting Forces as Applied to the Lathe; *William D. Stoppkotte; 1954; Northwestern University, Technology Institute, Evanston, Illinois.*

The principal problem of this investigation was to obtain quantitive results of cutting temperatures and cutting forces resulting from the turning of various steels on the lathe and to apply the findings in the improvement of cutting tool design.

3. Visual Inspection of Products for Surface Characteristics in Grading Operations; *E. P. DeGarmo, D. G. Malcolm; 1953; USDA Marketing Research Report No. 45; Supt. of Documents, Washington, D.C.*

Basic criteria for speeds of rotation and translation and description of approach with respect to the inspector were determined for the visual inspection of objects on a conveyor belt. Laboratory and field tests were conducted on two types of fruit and one type of vegetable.

4. HUMAN ENGINEERING. *(Motivation and Psychological Aspects, Physiological Aspects, Sociological Aspects, Biomechanics, Arbitration, Collective Bargaining, Labor, Training, Learning, Job Evaluation, Wage Incentive, Selection of Personnel). Also see 1, 2 & 3.*

4. An Analysis of Industrial Grievances with Respect to Source, Subject Matter and Level of Settlement; *Leo S. Soltys, Jr.; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An investigation of the grievances which have arisen in some twenty companies during the period 1951 through 1954. In order to have some basis for comparison between companies, grievances in various categories were recorded by number filed and number filed per thousand employees.

4. An Analysis of Selected Practices as Stipulated in Collective Bargaining Agreements in the State of Indiana; *Paul Joseph*

Kruggel; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.

The results of this study are based on one hundred and seventy-one Indiana contracts all of which were read from cover to cover. All results are stated in percentages.

4. An Analysis of Selected Practices as Stipulated in Collective Bargaining Agreements in the State of Indiana; *Don Brandt Millikan; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

One hundred and seventy-four Indiana contracts were read in compiling statistics for this study. Found that arbitaration is compulsory if requested by either side. An employee may be discharged for just cause after being suspended for some time period.

4,6. An Analysis of the Extent to Which an Engineer Identifies Himself with Management at Various Stages of Experience; *Henry E. Sodke, Jr.; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The study was designed to determine just how an engineer and student engineer identify themselves with management. The stages concerned were: Sophomore student engineer, Senior student engineer, non-supervisory engineer with less than five years service, and non-supervisory engineer with more than five years service.

4,8. An Analytical Study of "Learning Curves" as a Means of Relating Labor Requirements to Production Quantities; *Kenneth F. Hammer; 1954; Librarian, Cornell University, Upson Hall, Ithaca, New York.*

This study attempts to state the various factors which affect the labor inputs to production and to consider the rationality of the "learning curve" as a device for estimation. The mathematics of the formulation are presented and the various formulations found discussed. Several series of actual data (shipbuilding, punch press operations) are presented, relationship to psychologist's definition of "learning" discussed, and an attempt is made to relate the model to the Cobb-Douglas production function. Factors thought important in such "learning" are discussed.

4. Anthropometry in Aircraft Engineering Design; *Report No. SM-19587; J. A. Roebuck, Jr.; 1956; Douglas Aircraft Company, Inc., Santa Monica, California (Also see* **The Journal of Aviation Medicine,** *Feb., 1957).*

This paper describes a program developed by the engineering department of one airframe manufacture to compile and apply anthropometric data. Some specific applications of simple techniques found especially useful to engineering design and evaluation of commercial and military aircraft is described. Discussion of these applications indicate to interested investigators the nature of the data needed for further progress in the state of the art.

4,6. An Appraisal of Executive Development Training as Applicable to Naval Field Activities; *Herman Jennings Stansell, Jr.; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An appraisal of the executive development training program of the Navy Department for the purpose of establishing criteria and recommendations for the use in the naval ordnance field activities in establishing executive training programs.

4. An Appraisal of Factors Affecting the Productivity of Employees in a Naval Ordnance Plant; *Charles Priest, Jr.; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An evaluation and basis for comparison of manpower utilization and motivation in a government production activity. The evaluation was based on a questionnaire submitted to all employees in the producing group, consisting of industrial, quality, engineering and research and test departments.

4. An Appraisal of the Apprentice Training Program in a Naval Industrial Plant; *Samual Thomas Armstrong, Jr.; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An analysis and criticism of the apprentice training program in a naval ordnance plant, Indianapolis, Indiana, with the possibility of using this as a guide for establishing apprentice training in other naval industrial activities. Criteria for analysis were based on current publications and conferences with people active in the fields of apprentice training.

4,6. Some Aspects of Industrial Communications as Related to the Foreman; *Earl Somers Steeves, Jr.; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A study of how foreman's problems can be created through lack of good communications. How to achieve a feeling of security for the foreman by establishing communication patterns and procedures that will facilitate the transmitting of information in a downward, upward, and lateral direction.

4. Attitudes of Engineers in the St. Louis Area Toward Professional Unions; *Russell Elmer Gieselmann; 1955; Engineering Library, Washington University, St. Louis 5, Missouri.*

An examination of the reasons and motives for the attitudes of engineers toward professional unionism. In the group studied, all of whom were members of the Engineers' Club, a large majority were opposed to such unions. Certain social, and political factors were found to be involved in the formation of attitudes.

4. A Checklist for Human Factors in Operational Suitability Tests; *AFSWC-TR-55-17; Robert Fitzpatrick; 1955; Librarian, American Institute for Research, 410 Amberson Avenue, Pittsburgh 32, Pennsylvania.*

Operational suitability tests (OST's) require attention to human factors, in order to evaluate whether new Air Force equipment will function adequately in operations. A checklist of matters to be considered in planning for human factors in OST's has been developed.

4. A Critical Appraisal of Committee Utilization in a Naval Industrial Activity; *Gordon Hugh McCormick; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An appraisal of utilization of committees in a naval industrial establishment with the objective of arriving at conclusions which would apply specifically to the activity investigated. The criteria for use in investigation was developed from the literature outlining the advantages, disadvantages, and limitations of committees.

4,6. Development of Management Personnel for Foreign Operations; *B. Shivalingiah; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An investigation of the current trend and growth of the development of management personnel of United States companies with foreign operations and to obtain a summary of the practices of management development. This was accomplished by correspondence with the various companies.

4,8. Eliminative Waste and Wash Water Volumes in Air Transportation; *Report No. SM-14974; Fred D. Grundeman;*

1956; Douglas Aircraft Company, Inc., 3000 Ocean Park Boulevard, Santa Monica, California.

When excretory waste and wash water accumulated during a flight are to be stored until flight termination, efficient toilet design requires the specification of waste containers that will accommodate the most extreme accumulations without exacting undue space and weight penalties. This can be accomplished only if adequate information is available concerning the rates of accumulation of the wastes to be stored. The purpose of this study was to gather such information and formulate design recommendations accordingly.

4,6. Evaluation of Managerial Positions; *Henry Ludmer; 1955; Bulletin of the National Institute of Commercial Engineering, Chicago, Illinois.*

Evaluation of 31 factors pertaining to managerial positions using primarily weighted points for each factor. Determination of company policy, including salary ranges adopted by certain aircraft companies later on.

4,6. An Evaluation of Shift Worker Training Programs; *Robert F. S. Grieve; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

Research was carried out in relation to the Operating Division of a refinery. Some improvement to training efforts might be secured by delegating responsibility, seeking the advice and services of outside staff groups, and by negotiating a change in the union-management working agreement.

4. Human Tolerances to Transverse Acceleration; *C. E. Cunningham, D. W. Conover, H. Jacobs; 1957; Engineering Department, Human Factors Engineering Group (6-141), P.O. Box 1950, San Diego 12, California (Also see* **Meddelanhen Fran-OCH Naval Medicnska Mamnen).**

A total of 24 young male adults were centrifuged to physiological tolerance limit in time and force under two conditions: (1) without G suits and (2) protected by specially developed G suits. On the average, unprotected individuals evidenced subjective and behavioral tolerances to G forces somewhat in excess of safe physiological limits.

4,6. An Introduction to Two Recent Developments Leading Toward a Science of Communication; *Donald W. Arquett; 1956; College of Engineering, Oklahoma State University, Stillwater, Oklahoma.*

One is, the concept of "entropy in communication," which comes from the physical sciences. The other is "The whole man in his environment," a system concept which comes as a further maturation of the social sciences.

4. An Investigation of Hand Quality Picking of Small Objects; *Hans Richard Zimmer; 1956; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The aim of this study was to refine the basis for selecting successful operators and for the determination of hand quality picking conditions which maximize the picking rate. By means of aptitude tests nine operators, from a total of 47 students were chosen as experimental subjects. From a statistical and graphical analysis of the experimental data the following conclusions were drawn: (1) a battery of psychological tests was found to discriminate between aptitude characteristics of good operators and average operators. (2) an index of correlation between the scores on the battery of tests and the operators' picking rates of defective objects was found to be .877. This index is significant at the .001 probability level of linear correlation coefficients.

4. Knowledge of Learning and Methods of Training; *Robert Glaser; 1958; Measurement Laboratory and University Testing Service, University of Pittsburgh, Pittsburgh 13, Pennsylvania*

A description of the findings of psychological learning theory that might be applied to the design and development of training equipment and training programs.

4. The Measurement of Morale by the Mathematical Theory of Communication; *Raymond Curtis Stokes; 1953; Library, Oklahoma State University, Stillwater, Oklahoma.*

The morale survey has been presented as a feedback communication channel in the conceptual model of cybernetics. This channel is designed for the purpose of transmitting information about employee satisfaction and dissatisfaction from the employees or members of the organization to management or the decision center of the organization.

4. Merit Rating of Federal Employees; *Robert Eugene Weidner; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A proposed plan for rating to overcome several existing stumbling blocks. The plan lies within both the intent and letter of the law governing federal rating procedures. It requires the supervisor to analyze the jobs he supervises; requires him to let employee know what he is supposed to do and how he is doing.

4,8. Methods Analysis of Variable Height Features of Hospital Beds; *C. W. Israel and E. Sergakis; 1956; Library, University of Pittsburgh, Pittsburgh, 13, Pennsylvania.*

The purpose of this research study is to discover and specify features of the variable height hospital beds which will incorporate the easiest, quickest, less fatiguing, and most economical methods of operating the bed; the safest and most comfortable bed for the patient; and the soundest financial investment for the hospital.

4,6. Personnel Practices and the Concepts of Professional Employees; *Vincent P. O'Rourke; 1955, Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A company survey was taken and revealed almost uniform personnel practices toward non-supervisory professional employees. Almost five hundred professionals participated in an employee survey. Indicated considerable dissatisfaction with management's delegation of responsibility and authority.

4. Predicting Research Performance; *James W. Altman; 1953; American Institute for Research, 410 Amberson Avenue, Pittsburgh 32, Pennsylvania. (Report on Contract No. N 70NR-37007 —Project Designation No. NR 153-146).*

Results of the "Test for Selecting Research Personnel" given to 26 chemists and chemical engineers are given. Methods for evaluating these data and for job performance follow-up are given.

4. The Relationship Between Forearm Acceleration and Anthropometric Measurements; *Arthur Norman Paul; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Determination of the relationship between operators' forearm acceleration characteristics and their body and arm measurements. The forearm accelerations were plotted and analyzed to detect periods of constant velocity or periods of constant acceleration.

4,6. Seniority Policies and Procedures as Developed Through Collective Bargaining in the State of Indiana; *Sirous Bozorgmehry; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Determination of the prevailing industry seniority practice in

the State of Indiana. Conclusions are that the seniority principle has been more or less universally accepted by Indiana employers whose workers are unionized. Seniority is given greater weight in lay-offs than in promotions.

4. The Statistical Analysis of a Selected Sample of Labor Grievance Arbitration Cases; *Dwight Wadsworth; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An attempt to apply a minute amount of mathematics and statistics in an effort to analyze a sample of grievance cases from a given universe. The sample cases are from the first twenty volumes of the Bureau of National Affairs Labor Arbitration Reports.

4. A Study of Learning Curves of Industrial Manual Operations; *Matthias Arcef; 1957; Engineering Library, Cornell University, Ithaca, New York*

Describes a pilot study which is preliminary to a large scale investigation intended to yield a system for prediction of operation learning time. Mathematical models, experiments, and results are described.

4. A Study of Pension Plans for Small Businesses; *Robert Alexander McClelland, III; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The need for a critical study of pension plans is due to the fact that the life span of the nation's worker is getting longer. The plans studied in this thesis are of only the insured or partially insured type.

4,6. A Study of Some Dimensions of Team Performance; *Robert Glaser, Murray Glanzer and Alan W. Morten; 1955; Librarian, American Institute for Research 410 Amberson Avenue, Pittsburgh 32, Pennsylvania.*

This study attempts to develop a general methodology for the description and analysis of the behavior of task-oriented groups, or teams. The assumption is made that the group characteristics of a team are to be described in terms of the communication structure which exists between numbers. A set of 14 descriptive variables was constructed and then applied to various types of navy teams.

4. Summary of Human Engineering Research Data and Principles Related to Highway Design and Traffic Engineering Problems; *T. W. Forbes and M. S. Katz; 1957; Librarian, American Institute for Research, 410 Amberson Avenue, Pittsburgh 32, Pennsylvania.*

This report presents in brief fashion certain essential data and principles from various fields of human factor research that are applicable to highway design and traffic engineers. It points out that the driver's task is actually much more complex than is often appreciated and that engineering, education, enforcement and other traffic officials have an interest in reducing the requirements of his task. Appendicies contain abstracts of 35 relevant articles and an extensive bibliography.

4. A Technique for Displaying Task Analysis Information; *AFSWC-TN-56-11; Robert L. Weislogel and T. Owen Jacobs; 1956; Librarian, American Institute for Research, Kirtland Air Force Base, New Mexico.*

This report illustrates the use of a new technique for displaying a large quantity of task analysis information in a limited space. The example used is a portion of a high speed interceptor mission. Routine flight requirements are shown on a base page; requirements added to the pilot's job by weapon and fire control systems are shown separately on plastic overlay pages. When these pages are superposed on the base page, total job requirements are visible.

4. Untersuchungen über den Einfluss der Lichtintensitat auf das Elektroretinogramm (Measurement of the Amount of Light Intensity with the Electro-retinogram); *H. W. Muller-Limmroth; 1952;* **Zeitschrift für Biologie,** *Physiologisches Institut der Westf. Wilhelms-Universität, Munster/Westfalen, Deutschland.*

With respect to the eye, Fechners law can merely be confirmed within the range of medium intensities. The threshold of light sensation of the dark-adapted eye lies at $3{,}65.10^{-17}$ Watts per second. The light absorption of the refracting media of the eye is reported—for the different colors—with 16-37%, short light waves being absorbed to a considerably higher degree than long light waves.

4. The Use of Pictures and Diagrams in Job Description; *Edna M. Jones and Robert B. Miller; 1956; Librarian, American Institute for Research, 410 Amberson Avenue, Pittsburgh 32, Pennsylvania.*

This report represents a preliminary formulation of principles and examples for the preparation of pictorial and diagrammatic materials to support job descriptions. Essentially three questions are treated: (1) what are the theoretical considerations in the use of illustrations in support of written text? (2) what kinds of illustrations provide the best support of written text? (3) what techniques are available for illustrating job descriptions? An annotated bibliography is included.

5. ENGINEERING ECONOMICS *(Replacement Theory, Amortization Theory, Interest Rate Concepts).* Also see 3.

5. An Analysis of the Liberalized Depreciation Allowances Provided by the Internal Revenue Code of 1954; *George Ostroot, Jr.; 1955; Engineering Library, Washington University, St. Louis 5, Missouri.*

The results of this study show that the liberalized allowances will tend to promote the expansion and modernization of many industries through rapid recovery of investment capital. However, the primary reason for expansion of production facilities will continue to be product demand and availability of cash for financing the expansions.

5. The Development and Application of an Equipment Replacement Formula for Specific use in the Motor Bus Transit Industry; *Edward L. Culbertson; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Purpose is to develop a practical and economically sound replacement formula to be used in the transit industry which will aid in a more economic operation of the business. A sample problem is presented.

5. Evaluation of Investment in Production Facilities; *Feliciano M. Gonzales; 1953; Library, University of California, Berkeley 4, California.*

Comparison of four possible yardsticks of investment based on practice of 13 Bay Area companies. Results show that with the exception of two utilities, all make some use of pay-off periods, or if that is not applicable, use traditional rate-of-return method. Rate of return takes care of the "profits" question, and pay-off the question of "risks."

5. An Evaluation of Methods for Extending Stub Survivor Curves of Physical Property; *Samuel Ralph McClurd, II; 1954; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The purpose of this investigation was to evaluate the effectiveness of the Gompertz-Makeham Formula, Iowa Type Curves and

the Retirement Rate Method for extending stub survivor curves of physical property. These findings indicate the use of the Retirement Rate Method when a very accurate extension of relatively long stubs is required, the use of Iowa Type Curves for extending short stubs, and the use of Iowa Type Curves for reasonable approximations to longer stubs with a minimum of effort.

5. An Investigation of the Interest Rate in Engineering Economy Studies; *Robert Jerome Brown; 1953; Library, University of California, Berkeley 4, California.*

To present the businessman's choice of an economy study interest rate and find meeting ground between theory and business practice in selection of interest rate for engineering economy studies. Compares long-run future average earnings rate of firm's capital and rate of return on investment in question.

5,8,11. The Manufacturing Progress Function; *Richard W. Conway and Andrew Schultz, Jr.; 1957; Upson Hall, Cornell University, Ithaca, New York.*

A discussion of the manufacturing progress function, its mathematical structure, a set of tables simplifying its use, some results from an investigation of eight different plants, products varying from simple to extremely complex, volumes from 50 units to 200 million, are provided. Conclusions based on these results and an investigation in some depth in one firm are drawn. A procedure is suggested and outlined which, based upon customary product cost estimating methods, should result in improved estimates of varying costs of new products or design changes as these new items are "broken-in" for production. Suggestions for research are made.

5. The Performance of a Portfolio of Preferred and Common Stocks Between the Years 1926 and 1950; *Charles H. Schwarting; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

A study of the comparative performance of an investors portfolio, of preferred and common stocks, in 43 different corporations. The results of the study showed the average over-all performance of the preferred stocks to be superior to the average performance of common stocks.

5. Sale-leaseback Arrangements as a Financing Device; *Roger E. Emling; 1955; Engineering Library, Washington University, St. Louis 5, Missouri.*

An examination of the sale-leaseback arrangement as a financing device. The investigation includes consideration of the advantages to both the buyer and the seller and a summary of the opinions of some of the participants. A questionnaire was used.

5,11. A Study of the Relationship of the Business Cycle to the Principles of Engineering Economy; *Robert M. Eastman; 1955; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

A mathematical model of the business cycle was devised to approximate the fluctuations of the business cycle. Different parameters of the model were varied and different engineering economy methods were introduced. A comparison of the results of analysis modified by the cycle with the unmodified results furnished data on the effects of the cycle.

6. ORGANIZATION PLANNING *(Decentralization Concepts, Social Scientist's Aspects, Control Design, Communications, Information Theory, Organization Design, Financial Planning).* Also see 3 & 4.

6,8. An Application of Linear Programming to Production Planning; *Prauit Uawithya; 1957; Northwestern University, Technological Institute, Evanston, Illinois.*

The application of a mathematical solution of linear programming in production planning. Its major purpose is to illustrate a possibility of representing various interdependent factors in an industrial organization in a mathematical form.

6,12. The Design of a Short Course Program for the Executive Development of Engineers; *Robert Edward Eskew; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

The specific purpose of this research was to design a short course program which would aid in the development of the executive potential in engineers, especially engineers in Southern industry. Twenty-three executive development short course programs currently offered by colleges and universities, were studied. From the results of this research, the following conclusions were reached: (1) a short course program for the executive development of engineers is needed, and it is feasible. (2) the ideal short course program for the executive development of engineers is a series of three one-month sessions. (3) A three-month short course program for the executive development of engineers should include: 46 hours Personnel Administration, 44 hours Production Management, 39 hours Management Philosophy and Ethics, 36-½ hours Personal Development, 34 hours Finance Management, 31 hours Training Techniques, 31 hours Administrative Structures, 28 hours Marketing Management, 27-½ hours Managerial Accounting, 24-½ hours Public Relations, 18-½ hours Business in the American Economy.

6. Employee Interest in the Corporation Annual Report. An Opinion and Information Survey; *Maurice Peter Lux; 1955; Engineering Library, Washington University, St. Louis 5, Missouri.*

Survey covers salaried employees at all levels in one particular plant. Hourly paid workers were not studied. By means of an anonymous questionnaire, three main topics are explored in relation to the annual report: (1) employee interest, (2) qualitative information, and (3) quantitative information. Conclusion: report is not effective in communicating facts regarding results of the company's operations, but employees are interested in actual operations and future plans. It is believed that the report should be supplemented by such things as group discussions, simplified pamphlets, etc.

6. Management Perception: Phase 1—The Concept of Event-structure as a Perceptual Aid to the Manager; *Justus Theodore Schreiber; 1956; Library, Oklahoma State University, Stillwater, Oklahoma.*

A survey of the literature in the fields of anthropology, group behavior, information-communication theory, learning theory, organization and management theory, perception, psycholinguistics, psychology, psychiatry, semantics, sociology and social psychology to find a theory or theories which would extend Chester I. Barnard's management hypotheses to meet the problem of mathematical models.

6. Methods of Organization Study and Development; *Wilson J. Bentley; 1953; Library, Oklahoma State University, Stillwater, Oklahoma.*

The objective of this thesis is to present some of the methods of approach to an organization study; to point out some of the problems which may be encountered; to describe the analysis and presentation of the results of the study.

6. The Relationship of Technical and Non-technical First Line Management; *Homer Clint Carder, Jr.; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

Case study in the manufacturing department of a chemical plant. Relationships are investigated by the use of a questionnaire. A theoretical organization is presented based on sound organizational principles in order to increase the efficiency of the production department.

6. A Study of Activities in an Engineering Research Organization; *Vernon L. Hastings; 1955; College of Engineering, Oklahoma State University, Stillwater, Oklahoma.*

This study was to develop the basic information required for a comprehensive analysis of pertinent management activities in an engineering research organization.

6. A Survey of Industrial Engineering Practices in Industry; *Gale James Wilson; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An attempt to provide information concerning the existing industrial engineering concepts and practices of a representative segment of industry and educators. A questionnaire approach was used to gather opinions on the above subject.

7. INDUSTRIAL STATISTICS *(Sampling Concepts, Acceptance Sampling, Quality Control Techniques).* Also see 1.

7. Acceptance Sampling and Process Control; *Nicholas I. Salko; 1955; Engineering Library, Washington University, St. Louis 5, Missouri.*

A demonstration of a method for combining two separate forms of inspections into one operation during manufacture of the product. The method is applied to two different types of production processes and results in both a significant reduction of manufacturing costs and an improved quality product.

7,8. An Application of Combinatorial Statistics to the Determination of the Order Point; *Lawrence John Sespaniak; 1957; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An evaluation of the fixed order span on the calculation of the order point. A formulation of a method for incorporating the statistical aspect of the order span into the determination of the order point. A routine method is provided for calculating the order point.

7. Multi-level Continuous Sampling Acceptance Plans Based on Attributes, and Mathematical Treatise on Multi-level Continuous Sampling Acceptance Plans Based on Attributes; (Reports prepared by W. Grant Ireson, George Resnikoff, John E. Gessford and Robert V. Oakford) *1956; Quality Control Office, Air Materiel Command, Wright Patterson Air Force Base, Ohio. (Also see* **AMC Manual 74-23,** *U. S. Air Force).*

AMC Manual 74-23 contains approximately 56 different attribute acceptance sampling plans providing AOQL's of .025 to 15%, with one to five levels. Sampling tables, AOQ charts, and selection tables are included.

7,8. Sample Designs and Analyses for Service Tests of Military Weapons (finished assemblies); *Victor B. Kovac; 1955; Library, Georgia Institute of Technology, Atlanta, Georgia.*

An analysis was made of the factors which contribute to the quality of military weapons. Accuracy and reliability were investigated to determine simple and effective methods of proof testing and analyzing results. Two statistical methods found to be effective in evaluating dispersion are analysis of variance and regression of errors on range (distance).

7,11. The Use of Random Work Sampling for Cost Analysis and Control; *A. C. Rosander, H. E. Guterman, and A. J. McKeon; 1957; Statistics Division, Internal Revenue Service, Washington 25, D.C. (Also see* **The Journal of The American Statistical Association,** *June, 1958).*

Report reviews work sampling since Tippett and problems relating thereto; presents activity and cost arrays as models for random time sampling of work activity; describes in detail how random time sampling was applied to an entire division of 350 employees to obtain cost data for budget planning and control and presents some actual results; develops appropriate methods of estimating proportions, aggregates, and their sampling errors; and illustrates the application of these methods.

7,11. Work Sampling Techniques for Cost Estimation and Control; *A. C. Rosander; 1957; Statistics Division, Internal Revenue Service, Washington, D.C.*

Report explains why random time sampling works, derives basic random time sampling equation, explains how to determine sample sizes and sampling errors of estimated proportions and costs using employee minutes and cluster minutes as sampling units, analyzes problem of stratification, presents universal table for converting random numbers to random minutes, appraises alternative methods of calling random times and recording data, and proposes a block system for classifying and coding activities.

8. PRODUCTION CONTROL *(Inventory Control, Forecasting, Scheduling, Dispatching, Routing, Process Research, Product Research, Analysis and Measurement Techniques for Planning and Control, Receiving, Stockkeeping and Warehousing, Control Models and Simulation).* Also see 1, 3, 4, 5, 6 & 7.

8. An Analysis and Evaluation of Production Control Procedures for an Experimental Model Shop; *Irvin Emerson Poston; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

A discussion of reducing time and cost of making experimental models through the use of a satisfactory production control procedure. A discussion of "tailor-making" procedures that must be developed in each individual experimental shop to provide an adequate system of control over these problems.

8. Analysis of Factors Affecting Surface Finish of Gray Iron Castings; *Roger Lee Yard; 1955; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

The object of this experiment was to study the effect of the variables; sand fineness, mold hardness, and metal pressure on the surface finish of gray cast iron.

8. An Application and Evaluation of an In-patient Bed Assignment Control Board at the Kennestone Hospital, Marietta, Georgia; *Seymour Clarence Anderson, Jr.; 1957; Library, Georgia Institute of Technology, Atlanta, Georgia.*

This thesis was proposed to develop, install, operate, and statistically evaluate an effective method of forecasting and scheduling hospital in-patients by the use of an in-patient bed assignment control board similar in design to a Gantt Scheduling Chart. The results of the collected data indicate that the doctors' estimates of lengths of stay were of a satisfactory nature to be used as an actual length of stay when forecasting and scheduling in-patients to the Surgical and Pediatrics Sections of Kennestone.

8,10. An Application of Operations Research Methods to the Selection of a Processing Plan in a Meat Packing Plant; *Kenneth Austin Chatto; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The linear programming technique is applied to determine an optimum processing plan for smoked pork products. The limitations and assumptions of the use of the linear programming techniques are discussed.

8. The Design and Development of a Dielectric Heating Oven for the Baking Industry; *Hermann Bahlsen; 1954; Northwestern University, Technological Institute, Evanston, Illinois.*

The objective of this study was to design a device which, coupled with a standard radio frequency generator, could be used for baking crackers, cookies and other pastries. An attempt

was made to construct a device so that continuous processing of goods was feasible. In considering its commercial value, an economic analysis was made to study the possible applications in large scale or mass production.

8. Economic Coordination of Private Truck Fleets with Additional Purchased Transportation for Transfer of Intercity Freight; *James Malcolm Fiveash; 1957; Library, Georgia Institute of Technology, Atlanta, Georgia.*

An analytical and graphical investigation of common-carrier transportation costs was made showing the relationships between these costs and shipment weight and distance. Using these costs in the profit and loss sense, manufacturing economic principles and theories are applied to the transportation problem. The various factors which affect the expense functions of the private fleet and the transportation charges for common-carrier services are presented, and the manner in which these factors influence the private fleet gain is given by graphical analysis.

8. Economic Factors in Short Term Sales Forecasting; *Mathew S. McCauley; 1953; Engineering Library, Washington University, St. Louis 5, Missouri.*

A study of forecasting methods now in use, particularly correlation with economic indicators. Results indicate that a combination of several methods should be used and that correlation with economic indicators could be used as external checks.

8. Evaluation of a Forecasting Consultant Service as a Management Tool; *Gerald Vincent O'Connor; 1954; Engineering Library, Washington University, St. Louis 5, Missouri.*

This investigation compares forecasts of business activity made by a professional service with the actual conditions which developed. Results indicate that no appreciable contribution was made by the professional forecasting service.

8. An Exploratory Survey of the Scheduling Practices in a Selected Group of Furniture Manufacturers in Indiana; *Hubert Theron Cornish; 1953; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

To develop and test a questionnaire for the determination of what scheduling practices are being used. Results showed very little scheduling being done with very little uniformity.

8,9. An Investigation into the Proposed Use of Electronic Data Handling Machines for Production Control; *Leonard Hayet; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

Investigation of the theory behind, the present status of, and the future potential for using electronic data handling machines in production control. A computional procedural system is proposed which makes use of rapid electronic computing and handling devices to process the masses of data on variables.

8. Mathematical Programming of Open Hearth Furnace Operations; *Victor John Tilly; 1956; Engineering Library, Washington University, St. Louis 5, Missouri.*

Investigation to determine a quantitative basis for management decisions on open hearth furnaces and material scheduling. Emphasis on maximization of over-all profits. Data for statistical analysis was collected by random sampling. Effects of variation in the factors controlling the outcome of the open hearth process were expressed in terms of production rate and cost per ton.

8. A Production Control Method for Prognosticating of a Medium Sized Industry Employing Job-lot and Semi-serialized Manufacture; *Gerald Carl Maechler; 1956; Engineering Library, Washington University, St. Louis 5, Missouri.*

Case study of a particular company whose problem was large fluctuations in direct labor requirements. An analysis of the plant functions was made with the end in view of enabling the plant to enjoy the savings gained by utilizing men and machines to best advantage. A generalized procedure is suggested.

8. Statistical Analysis of Factors Affecting Casting Finish; *Jerry E. Goldress; 1954; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

The effect of three factors: sand fineness, metal pressure and wood flour on casting finish was investigated by means of a latin square statistical design. Sand fineness and metal pressure were found to be significant and wood flour not significant in their effect on casting finish.

8. The Use of Photographic Techniques in Making the Physical Inventory; *Murray R. Raymond, Jr.; 1955; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

The establishment and evaluation of a method of making the periodic physical inventory by photographic methods. The possible use of photographs to secure a physical count of inventories with the considerations of cost, time, savings, and accuracy of count is the problem investigated in the study.

9. DATA PROCESSING SYSTEMS DESIGN *(Digital Computers, Analog Computers, Accounting Equipment, Desk Equipment, Auxiliary Equipment, Analysis Techniques).* Also see 1 & 8.

9. Capabilities and Limitations of Electronic Computers; *Henry Ludmer; 1956; G-3, 5th Army Hqs., Chicago, Illinois.*

General and special capabilities of automatic computers as well as their limitations with regard to G1, G2, G3, etc. operations, including principles of programming.

9. Characteristics of a Proposed Data Processing Center for the Support of the United States Air Force Logistic Operation; *John F. Clyde; 1957; College of Engineering, Oklahoma State University, Stillwater, Oklahoma.*

The changes in capabilities and design of the weapons systems projected for the United States Air Force must be reflected in the logistic system of that period. The growing might of nuclear and missile weapons demands dispersion of military bases and a capability for instantaneous retaliatory actions in the event of war. This environment and the tremendous size and scope of the supporting logistic activities make essential the use of electronic data processing equipment. The purposes of this study were: (1) to formulate the principles involved, and to structure an organization for a data processing system to support Air Force logistics operations and (2) to determine the gross characteristics of an electronic data processing equipment system.

9. A Study of the Developmental History of Selected Complex Electronic Systems; *Robert B. Miller; 1956; Librarian, American Institute for Research, 410 Amberson Avenue, Pittsburgh 32, Pennsylvania. (Also see Air Force Personnel and Training Research Center Technical Report AFPTRC-TR-56-1).*

The purpose of the study was to determine what kinds of maintenance related information become available during stages of development of complex electronic equipment, and to consider the usefulness of this information for the early planning of personnel training programs. Developmental products have been identified which provide data for forecasting job requirements for maintenance.

9. System Surveys-check List and Sample Reports; *Henry Ludmer; 1953; Roosevelt University, 430 S. Michigan Avenue, Chicago 5, Illinois.*

Principles and practices of systems and procedures, including detailed check lists and system survey reports.

10. OPERATIONS RESEARCH AND SYSTEMS DESIGN *(Linear Programming, Waiting Line Theory, Simulation Concepts, Game Theory, Monte Carlo Concepts, Probability Theory).* Also see 3 & 8.

10. Development of a Systematic Method for Solving a Special Assignment Problem; *William Allen Skagerberg; 1956; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

This study considers an assignment problem with unusual relationships between its components and develops a method for determining a feasible solution for the problem. Specifically, the study is concerned with fixed transmitters in a broadcasting system with known radiation patterns (areas of influence). These patterns contain two boundaries or contours which define the service area and the co-channel interference area. It is desirable to use the least number of frequencies (subdivisions of the continuous variable) possible to satisfy the operation of these transmitters without creating co-channel interference.

10. An Introduction of Linear Programming to Industrial Engineering; *William Kahlen Doty; 1954; Inter-Library Loan Service, Purdue University, West Lafayette, Indiana.*

An explanation of what linear programming is, how to interpret a problem mathematically, how to solve a simple problem, and how to set up for solution a few examples of feasible problems. The emphasis is on Industrial Engineering and requires no knowledge of mathematics beyond college algebra.

10. Operations Research; A Methodology Useful in Making Management Decisions; *T. R. Bunnell; 1955; Central Library, The Pennsylvania State University, University Park, Pennsylvania.*

This study deals with a series of problems investigated by an Operations Research Team in a radio tube manufacturing plant; how this team applied the Operation Research Methodology; and the results realized by the plant management from the activities of this team.

10. Queuing Theory and its Industrial Applications; *Alberto B. Araoz; 1956; Librarian, Cornell University, Upson Hall, Ithaca, New York.*

A survey of queuing theory with discussion of its development, tabulation, and anticipated applications.

11. COSTS AND COST CONTROL *(Accounting Concepts, Inspection, Budgets, Control Procedures, Purchasing).* Also see 1, 3, 5 & 7.

11. Single Family Dwelling Construction Cost Minimization; *W. T. Crinnion; 1957; Library, University of Pittsburgh, Pittsburgh 13, Pennsylvania.*

The approach in this research is to examine the detailed unit costs of all the alternative elements of which any house is constructed, and then to manipulate these various elements into an aesthetic, practical, least cost design.

12. INDUSTRIAL ENGINEERING EDUCATION Also see 6.

12. An Analysis of the Requirements for the Degree of Master of Science in Industrial Engineering in Academic Institutions; *W. H. Johnston; 1957; Library, University of Pittsburgh, Pittsburgh 13, Pennsylvania.*

The rapid growth of graduate study in industrial engineering in recent years has introduced many new problems and accentuated existing problems in connection with the study for the master's degree. A survey disclosed that little organized or concerted effort had been given to these problems. This study was undertaken in order to indicate these problems more clearly and to establish the basis for evaluation and possible eventual elimination of the major areas of conflict.

12. Course Scheduling with the Digital Computer; *J. E. Brubaker and P. M. Dargay; 1957; Library, University of Pittsburgh, Pittsburgh 13, Pennsylvania.*

The purpose of this research is to develop a program for an IBM 650 computer to be used for determining semester course schedules for each student in the Industrial Engineering Department. Program includes recognition of course priority, prerequisites, corequisites, minimum and maximum credits allowable, and other decisions commonly required to be made by a staff member in the pre-planning of student schedules.

12. Production Management and the Laboratory Method; *W. Nye Smith; 1957; School of Business, Indiana University, Bloomington, Indiana.*

A survey of about 100 U.S. colleges, ⅔ Industrial Engineering and ⅓ Business Administration, to indicate curricular pattern and extent of laboratory teaching in Production Management courses. Much of the study is based on personal visits and interviews. Analysis emphasizes criteria for use of the laboratory method and differences in application. Conclusion indicates need for more laboratory work in Business Administration colleges, and more careful planning in all colleges to prevent a decline in laboratory teaching due to increasing cost reduction emphasis.

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Current job openings are published in condensed form in each issue.

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Each job opening is assigned a "P" number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

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Employers having openings for qualified Industrial Engineers are invited to list them. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service.

Industrial Engineers are often employed in such fields as Work Measurement, Production Control, Plant Engineering, Operations Research, Industrial Relations, Sales, and Management. For a more complete coverage, see the following list of job classifications. Please do not hesitate to forward information on jobs in any area where it is recognized that an Industrial Engineering background will be of value.

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INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required		
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range
								from / to
1	Consult.	Ill	×	Broad			7–10	30 / 38
6	Warehouse	NJ		94				
17	Air Force	O		11, 13, 42, 31, 38	7.5–9		4–5	
20	Electric, Mfg.	Mo						
23	Education	NY		10, 30, 40, 50	6–10			
31	Paper Mill	Wis		11, 45, 80, 70, 32			1–5	30
34	M. Consulting	O	×	30, 40, 53, 71			4	27
41	M. Consulting	O	×	10, 21, 31			5–7	
42	Hospital	O		10	4.8–7.2			
49	Graphic Arts	Ill		11, 20, 42, 43, 70			3–5	25 / 35
67	Army Ordnance	Pa		11, 13, 34, 71, 72, 73	6.2–7.4		2–3	35 / 55
72	Airline	Ill		70, 42, 43				
75	Army Ord.	Ill		13, 31, 37, 70	7–9		2–4	
79	Mining & Smelt	NM		10, 20, 30, 40			6–9.4	45
86	Public Utility	DC		10, 11, 13, 18, 37, 42, 43			2–3	
89	Foundry	Cal						
91	Syn. Fibers & Films	Pa, Va, W Va		10, 20, 42, 43, 72			0–5	
93	Foundry	Ill		11, 19, 30				
106	Sugar	Md, La, SC, Conn		13, 43			0	
108	Consulting	Overseas	×	10, 20, 60			10	35 / 40
113	Chemicals	NJ		62				
119	Paper	Ga		10, 20, 30, 42, 43, 53	6.0–7.2			
123	Printing	NY		49, 53			2–4	
140	Magazine-Editorial	Mass		43	5.0–7.0			
141	Steam Electric Power	Toronto		93–80	11.0		13 (P.E.)	35 / 45
145	Lithography	Vt		31			2	
155	Electronics	Texas		11, 13			3–	
156	Plastics	Texas						
163	Govnmt Inspection	O		37	6.4–7.5		7–	
167	Weapons Systems	Wash DC		50		Ph.D.		
168	Education	Mich		92	6.0–7.5	Ph.D./M.S.	1–5	25 / 55
172	Power Shovels	Pa, Wisc, Ind		11, 13, 21, 32, 39				
177	Education	NY		50+General I.E.		M.S. or Ph.D.		30 / 45
181	Bldg. Maint.	Mich		31, 38, 48				
184	Education	Pa		10, 47, 54, 81				
185	Chem. Plastics & Resins	Conn		50, 52, 37, 30, 36		M.S.	–5	30
186	Chem. Plastics & Resins	Conn		11, 26, 36			1–4	28
187	Glass	Tenn		43, 81				

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
188	Education	Mass		Asst. Prof. (50)	5.1–6.5	M.S. or Ph.D.			
189	Agric. Marketing	Maine	×	10, 42, 43, 53	7.5		2½		
191	Agric. Marketing	Wash. DC		10, 42, 43, 53	5.3		½		
192	Air Force Base	Ala		11, 13, 15, 16	4.5–7.5			18	
193	Pharmaceuticals	Ind		13, 21, 42, 44, 50, 55, 70	5.4				
194	Airline	Cal		11, 31, 36, 42, 43, 45, 71			4–15	25	35
196	Navy	Pa	×	13, 33, 42	7.4		2½		
197	Aircraft	Wash		I.E.	5–10		2	25	40
198	Paper Converting	Mo		13, 19	6–		5	30	40
199	Govt. Agency	Panama		Engr. Trainee	5.6–6.7			20	
200	Electronics	Texas		31, 33, 35, 38, 54, 70	7.2–9.6		3–		
201	Electronics	Texas		42	6.5–7.2		3–		
202	Electronics	Texas		11, 19, 33, 35, 38	6.5–8.0		5–		
203	Electronics	Texas		19, 38	7.2–8.6				
204	Heavy Mtl. Working	NY, Pa, NJ		14, 15, 19, 21			1–7		
205	Heavy Mtl. Working	NY, Pa, NJ		11			5–		
206	Army Ordn. Depot	NJ		10, 11, 13, 15, 16, 21	6.0–8.5		2–		
207	Textile Mfg.	NC-SC		45, 46, 42, 43, 21, 32	9.0–12.0				40
208	Mtl. Stamping Mach.	Wisc		10, 11, 13, 16	9.0–12.0		5–	28	40
209	Consulting	Ill-NY	×	50, 51, 52	9.0–15.0				
210	Mfg.	NY, NJ, Fla, Cal, Ill		54, 50 (Military)	10.0–13.0				
211	Mach. Mfg.	Texas		92–	10.0–15.0				40
212	Metal Fbr.	Ia, Minn, Mich		91	8.0–10.0				37
213	Aircraft Repair & Mod.	Cal		15, 32, 42, 43, 44, 53	7.5		2½	21	
214	Airforce Depot	NY		13, 31, 40	4.4–7.4				
218	Ammunition Depot	Wash		10, 30, 40, 50, 70	7.4		2½		
219	Air Force	Utah		10, 11, 13, 14, 15, 16, 18, 19	7.4		2½		
220	Agric. Service	Ariz, Colo, NM, Utah, Wyo		11, 32, 33, 42, 44, 66	4.5–10.3				
221	Sugar Refining	Conn, Pa, Md		10, 31, 36, 38, 40, 53	5.5–7.2		0–5		30
222	Education	Mont		37, 51, or 54	6.5–7.5		3	24	
223	Navy Ship Repair	Guam		94–42, 44, 48, 49	6.4 plus 25%				
225	Post Office	Wash DC	×	Ind. Eng.	7.4–11.3		4		
226	Silverware	NY		92–13, 21, 42, 11			10	35	45
227	Heavy Steel Fabr.	O		91, 11, 43, 54, 70	6.0–8.0		5+	35	45
228	Navy Overseas Bases	Pacific							
229	Bakery	Mo, Cal							
232	Air Transport	Okla		13	5.4–7.4		1–2	21	35
233	Air Lines	Okla		11, 36, 53	5.8–8.0		4–	25	40
234	Plumbing Goods	WVa or Texas		10			2		
235	Knitting Apparel	NC		10–20	5–8		0–5		45
236	Printing	Ill		91–30, 50	12.0–14.5				
237	Consulting	Ill	×	10, 20, 30/50, 70, 90	9–12		10–	33	45
238	Chemical Processing	Tex		41, 45, 31	7–8		5	28	40
239	Chemical Processing	Tex		11, 13, 42	7–8		5	28	40
240	Chemical Processing	Tex		43, 81	7–8		5	28	40
241	Mfg., Oilfield Equip.	Tex		32, 11	7–8		3		
242	Elect. Mfg.	Tex		91–11, 63	9–9.5		5	28	40
243	Food Processing	Tex		32 in Foods	6–7.5		3	25	35
244	Steel Ind.	Mich		10, 11, 13, 15, 21	5.3–5.8		0–2	23	33
245	Steel Ind.	Mich		10, 11, 13, 15, 21	7–8		3–5	26	38
246	Paper & Bag	Ala		33, 34, 35, 51, 54, 71, 73, 91					
247	Navy	Guam		92–13, 36, 42, 48, 70	8.8		3		
248	Auto Seat Covers	RI	×	95	12.0–18.0		5–10	32	40
249	Chemicals	WVa, Cal					5	25	35
250	Food (Canning)	Ill		14	6.6—8.4		5	28	35
251	Food (Canning)	Ill		14 (Trainee)	5.4		0	21	28
252	Sugar Refining	Md		11, 38, 42, 43, 48, 49	5.6–7.0		0–4		30
253	Mail Order, Genl. Mdse.	NY		11, 18, 71, 72, 73	5.0–7.0		2–3	25	30
254	Education	Mass		Asst. Prof.—I.E.	5.1–6.5	M.S.-Ph.D.			
255	Railroad	Overseas	×	36	Open	B.S. Plus	10	30	
256	Frozen Foods	Overseas	×	42, 44	Open	B.S.	10	30	

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement
12	Suggestion Systems
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

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Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.